

# EDN<sup>®</sup>



Choosing a precision  
voltage reference

Serial techniques for  
microcomputer peripherals

Fast comparators

Software for  
multiple-PLD designs

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ELECTRONIC MANUFACTURING MANAGERS

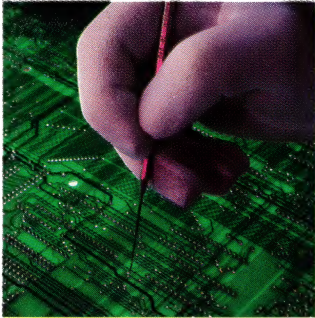
## Innovations in hardware ease assembly process





# No "boomerang effect" at Trend Circuits. Less than 1% of our prototype boards ever come back.

**F**ast turnarounds in prototype circuit boards are great — but not when the boards circle back again and again because of poor quality.



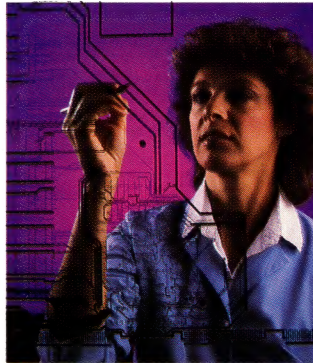
That "boomerang effect" costs precious time in proving your concepts and can end your chances to meet critical market windows.

**We deliver speed  
and quality.**

Speedy turnarounds don't count for much if proto-

types don't work. At Trend Circuits, we're specialists in rapid production of prototype boards that work first time out. That's because we're people who understand your language, your objectives and your pressures.

Further, fully one-third of our people are involved in inspection. We begin with incoming artwork, where we can quickly identify common design errors. And we continue with double- and triple-checking right through to completion. As a result, less than a scant 1% ever come back. And that's good for both of us.



Now for speed. On a regular basis, we deliver *double-sided boards within 24 hours, and multi-layer boards within five days*. In fact, we're completing no less than 82% of all our work within five days.

**Check our references.**

You can verify our facts easily enough by talking to our customers. Simply phone and we'll put you in touch with people who've decided they won't accept compromise in quickly moving from design to finished prototype. They'll tell you why we're their logical choice for "no-boomerang" boards. And why we should be yours.

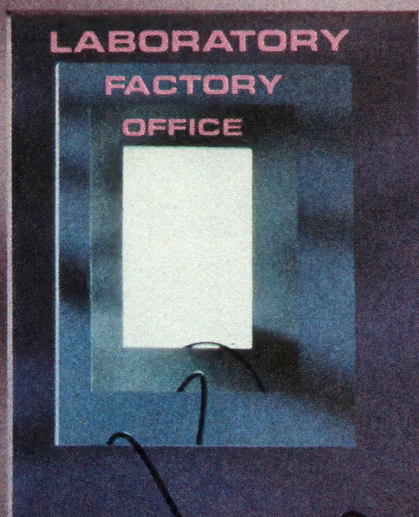
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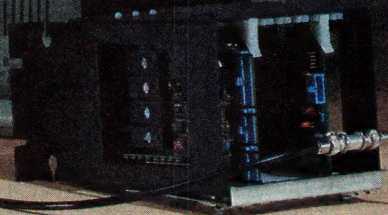
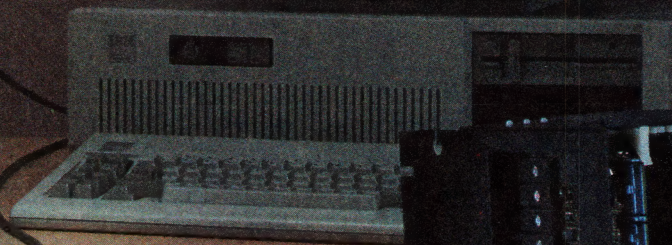
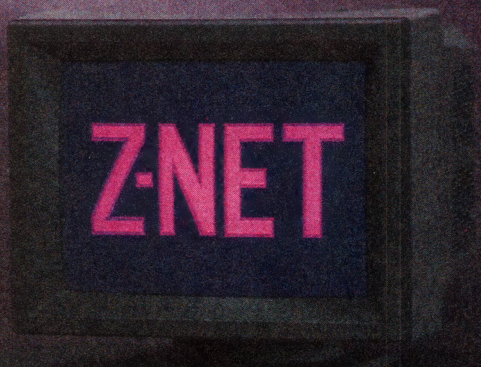


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## New Simple To Use Network Expands Power of STD Systems



### Turnkey industrial networking for STD Bus and personal computers

Z-NET is a complete, simple to use network for industrial applications. Z-NET extends the capabilities of Ziatech's PC DOS-based STD Bus systems by allowing them to share information and resources with other STD systems and IBM-compatible personal computers.

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Ziatech's STD and PC network controllers are based on the well-established ARCNET protocol, and are supported by ViaNet, a software package from Western Digital that makes using the network as easy as making simple DOS calls.

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Z-NET was designed to meet the specific network needs of industrial STD Bus computers, which are typically unattended or embedded in equipment. Z-NET makes an ideal sub-network in a large factory or a total solution for smaller applications.

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For a complete technical brochure and configuration guide to a complete STD and PC network, call Ziatech today. (805) 541-0488



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# PUNCH UP YOUR FLASH A/D PERFORMANCE.

## FREEZE VIDEO SIGNALS WITH A SAMPLE & HOLD AMP LIKE THIS.

Introducing the VA730 High-Speed Sample & Hold Amplifier . . . the only monolithic IC of its kind that operates in the 50MHz range.

The only one that's available in surface-mount packaging, and in both commercial and military grades.

And the only one that's designed specifically to operate with 8-bit flash converters.

Best of all, not only is it less costly than expensive hybrids, it's priced well below competing Japanese monolithics.

The VA730 has an A/D converter reference power supply, a sample & hold function, and an ECL clock output section operating to a frequency of 50MHz.

It's available in a 14-pin cerdip package, in a 20-pin ceramic leadless chip carrier (LCC), and in die form.

The VA730 Sample & Hold Amp is just part of VTC's broad line of Linear Signal Processing (LSP) ICs, which includes Op Amps to 500MHz gain bandwidth . . . precision, high-speed, and fast settling, plus dual and quad . . . with no sacrifice in performance.

A/D Converters to 12 bits, 1μsec conversion.

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And Operational Transconductance Amplifiers to 50V/μsec, 75MHz.

Quite simply, if your analog application requires high performance, you should be specifying VTC's LSP ICs!

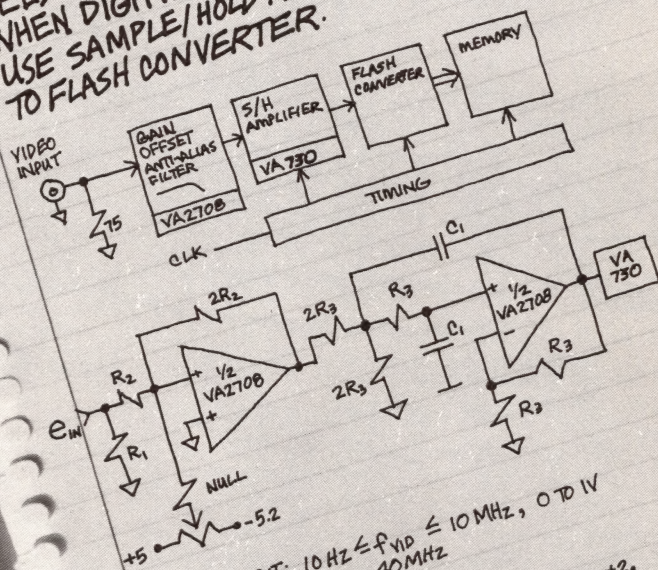
Most of these standard parts are also available as cells in our 6GHz Linear/Digital Bipolar Standard Cell Library, the VL3000.

They all feature ±5V operation, which means they help simplify your system power requirements, and reduce power consumption.

For samples and data sheets on the VA730, or any of our LSP products, call toll-free or write us today: VTC Incorporated, 2401 East 86th Street, Bloomington, MN 55420. (In Minnesota: 612/851-5200.)

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NEED TO MINIMIZE DISTORTION WHEN DIGITIZING VIDEO SIGNALS: USE SAMPLE/HOLD AS COMPANION TO FLASH CONVERTER.



VIDEO INPUT:  $10\text{ Hz} \leq f_{\text{VID}} \leq 10\text{ MHz}$ , 0 TO 1V  
 CLOCK RATE:  $f_{\text{CLK}} = 40\text{ MHz}$   
 S/H GAIN = 0 TO -2V

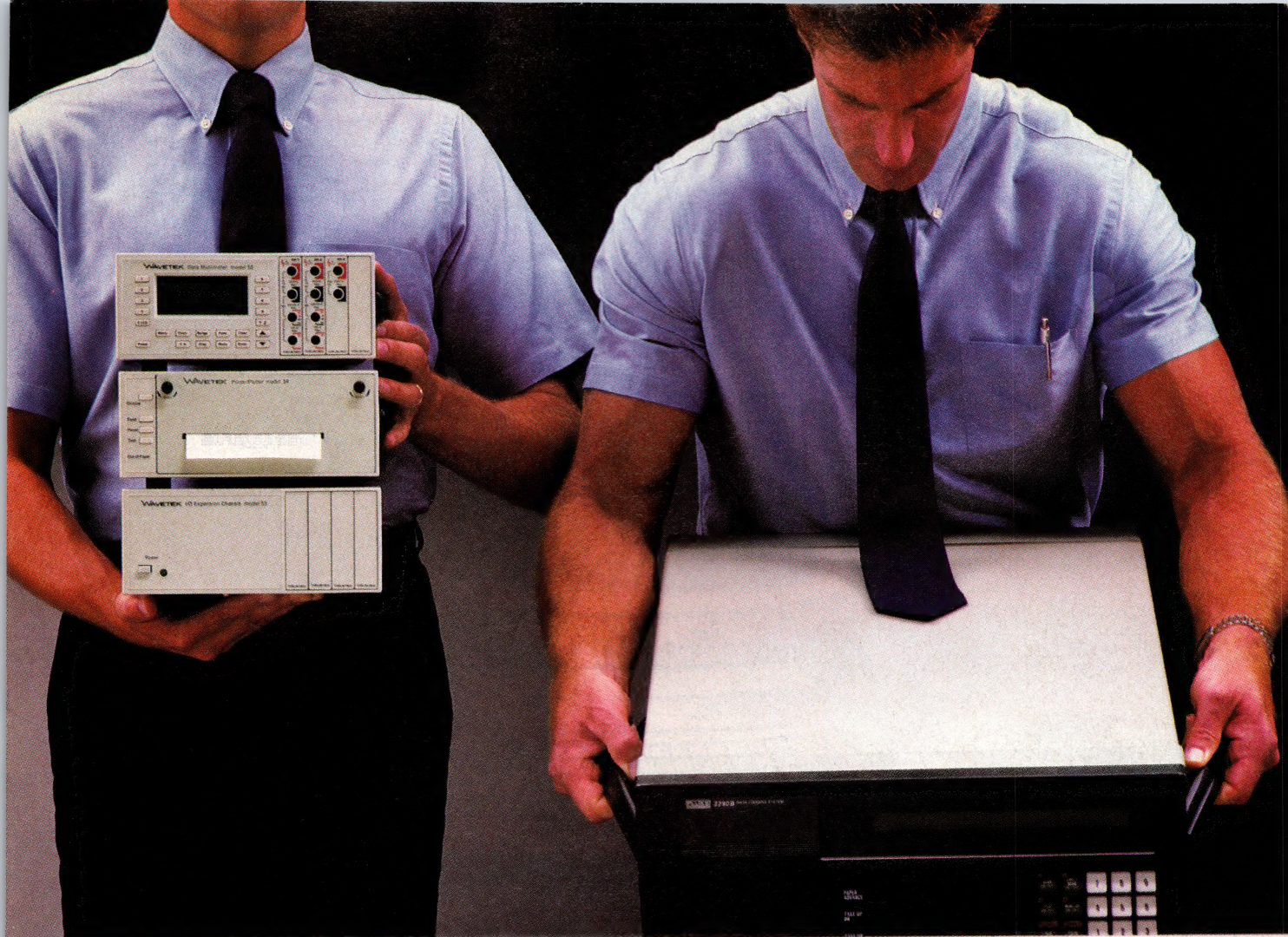
DESIGN APPROACH: USE DUAL VA708 FOR GAIN = +2,  
 OFFSET AND ANTI-ALIAS FILTERING.  
 USE SAUEN-KEY TYPE 2ND ORDER FILTER,  $Q=1$ .



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CIRCLE NO 9





# Side by side comparison of our data logger and theirs.

Wavetek has brought an exciting new dimension to data logging—small. Our Series 50 Data Logger is a fraction the size and considerably less expensive than the one on the right. And our data logger is light enough to be easily carried by mere mortals. When you compare the rest of the features, the competition drops right out of sight.

For instance, the Series 50 Data Logger scans 260 channels, provides digital and stripchart printouts and can operate on its internal battery for days, storing

up to 100,000 readings in non-volatile memory.

Even more amazing is what the Series 50 measures, including:

- **DC Volts and true RMS AC Volts**
- **Temperatures, 6 Thermocouple Types, °C, °F, °K**
- **AC/DC Current**
- **DC Watts, AC Volt-Amperes**
- **dBw, dBm**
- **Frequency and Period**
- **Pulse Width, Time Interval**
- **Events (Counter)**
- **Resistance and Continuity**
- **Diode Junction Voltage**

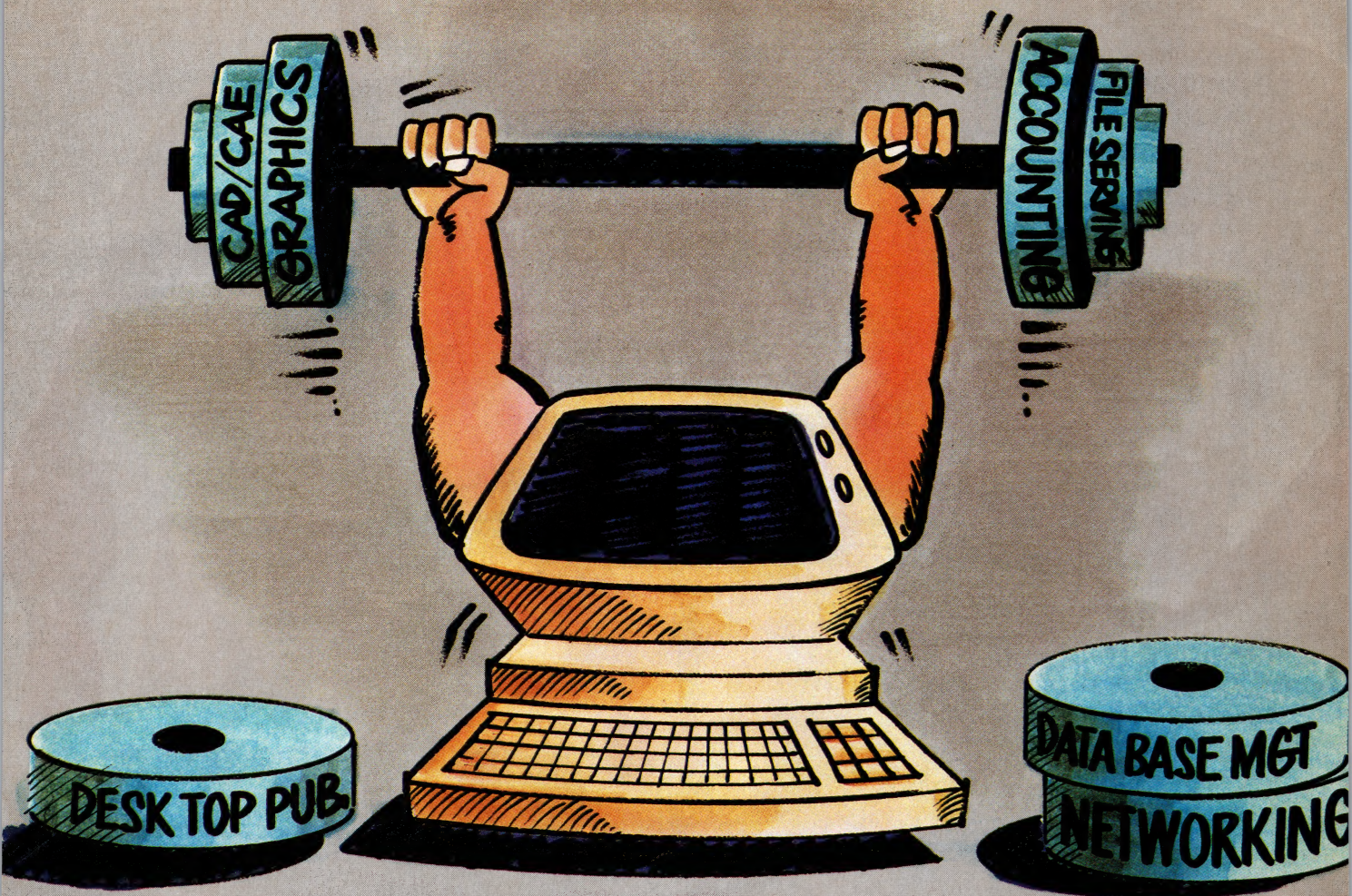
All are STANDARD FEATURES, not options! In addition, there are four independent A/D converters, so you can make four different types of measurements simultaneously.

We could go on for pages, but rather than weigh you down with specifications, we'd rather show you how Series 50 will make your job easier. Please call, or write for our brochure. Wavetek San Diego, Inc., P.O. Box 85265, San Diego, CA 92138. Tel. (619) 279-2200; TWX 910-335-2007.

Circle 3 for literature

Circle 42 for demonstration





## NCR BOOSTS PC POWER!

Think of what an IBM or IBM-compatible PC could do with 25% more power! Bigger system memory and/or enhanced work station performance could become instant reality.

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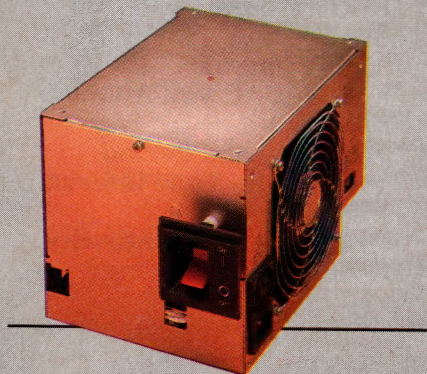
existing PC-AT supplies, it may be installed as a direct replacement in existing machines. It is internally fan-cooled.

The unit delivers 280W (compared with the 220W rating of typical earlier designs). Outputs are +5, +12, -5 and -12VDC.

If you're designing a new compatible PC or implementing an especially power-hungry applica-

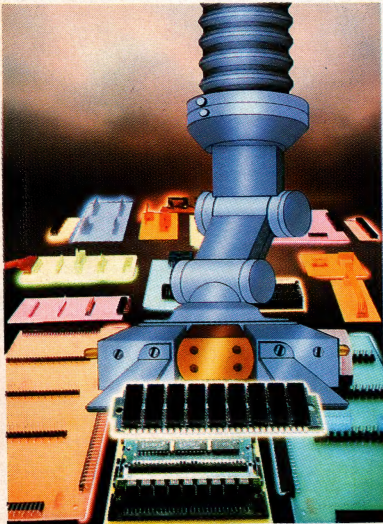
tion, this new NCR digital switcher will give your microcomputer the added muscle it needs. It can be a real performance enhancer for CAD/CAE/CAM/CIM, file serving, graphics and other work station capabilities.

For detailed specifications and prices, contact NCR Power Systems, 3200 Lake Emma Road, Lake Mary, FL 32746-3393. Telephone 1-800-327-7612.



**NCR**





*On the cover: Advances in materials and hardware can ease your design through the production phase of the product-development cycle. See pg 148. (Photo courtesy Molex Inc)*

## DESIGN FEATURES

### Special Report: Materials and Hardware 148

High density and performance are goals for today's VLSI- and SMT-based designs. Fortunately, advances in materials other than silicon are keeping pace with advances in integrated circuits.—*Tom Ormond, Senior Editor*

### Programmable array serves as a controller for dynamic RAMs 169

Large memory systems that use dynamic RAMs often have varying requirements for control. A programmable gate array can offer flexibility to meet the needs of various memory-system applications.—*Thomas Waugh, Xilinx Inc*

### Selection criteria assist in choice of optimum reference 183

It's not always easy to select the most suitable precision voltage reference for your application. An overview of selection criteria can help you make the choice.—*Ron Knapp, Maxim Integrated Products*

### Serial techniques expand your options for $\mu$ C peripherals 199

The Serial Peripheral Interface (SPI) bus of the MC68HC11 microcomputer is flexible enough to let you attach devices designed for other serial buses—Signetics' IIC peripherals, for instance, or ITT's IM family.—*Naji Naufel, Motorola Inc*

### Programmable-delay ICs control system timing 209

Low cost, low power, and small package size extend the application of digital-to-time converters in system timing applications. By exploiting the programmability features of these devices, you can both simplify timing-system design and gain greater control of timing parameters.—*Craven Hilton and Jeff Barrow, Analog Devices Inc*

### Precision comparators ease oscillator and data-converter design 219

To simplify the task of designing high-performance circuits such as a crystal oscillator and an ATE pin receiver, you can use a comparator that combines low bias current, high gain, high speed, and 3-state outputs.—*John Dutra and Barry Harvey, Elantec Inc*

*Continued on page 7*



VBPA ABP



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# What 202 tiny shock absorbers do to "keyboard clatter"—and "keyboard feel"



**Q**uestion: What kind of person would build two tiny shock absorbers into every key of a new tactile keyboard? Answer: The same person who replaced the mechanical switch other keyboard makers use with an entirely new design — to prevent noise and vibration every time a key is pressed.

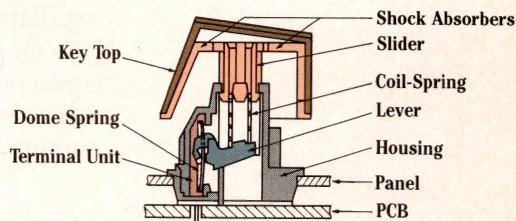
And what does this kind of perfectionism get you? A remarkably quiet tactile mechanical keyboard that's extremely reliable: up to 30 million key-strokes per key.

But to understand the best thing about Fujitsu's new FKB1000 Series keyboards, just type on them. The keyboard feel is crisp and positive, with a distinct 15g tactile return. And no clicky, clacky keyboard clatter.

When you want a keyboard for your next PC or terminal, remember Fujitsu's little shock absorbers. Your customers can't see them (and they certainly can't hear them). But they'll know they're there by the way they feel.

And so will you.

101-key (U.S.) and 102-key (European) keyboards available.



## FKB1000 Series Keyboards

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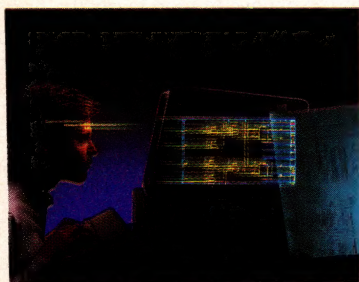
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For help in designing with multiple PLDs, you can turn to a variety of recent software packages, which range from the simple to the very powerful (pg 61).

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## TECHNOLOGY UPDATE

### PLD-design software meets the challenge of multiple-device PLD applications 61

Until recently, engineers have tried to implement as many logic functions as they could in a single programmable-logic device in order to use as much as possible of the device's internal circuitry.—*Charles H Small, Associate Editor*

### Growing array of 1-chip dc/dc converters provides power for diverse applications 73

The increasing variety of chip-level dc/dc converters is not only changing the way system designers structure conventional power supplies, but is also providing solutions to applications problems that were previously satisfied only by more costly and cumbersome approaches.—*Dave Pryce, Associate Editor*

### New software tools run IBM PC software on a variety of 32-bit $\mu$ Ps 93

Most industry observers agree that the vast wealth of MS-DOS-based software is what gives the 8086  $\mu$ P family such a decided advantage over other  $\mu$ Ps. That situation is changing, though.—*Robert H Cushman, Special Features Editor*

### Buscon/88 West offers technical programs, seminars, and presentations galore 105

All computer-bus users should put Buscon/88 West high on the list of shows and conferences they plan to attend.—*EDN Staff*

## PRODUCT UPDATE

Ripple-and-noise test module	119
Systems digital multimeter	123
D- and E-size electrostatic plotters	126
Monolithic A/D converter	128
5½-digit programmable multimeter	130

## DESIGN IDEAS

Comparator circuit monitors window events	235
MOSFETs provide low-loss rectification	237
Temperature sensor has 4- to 20-mA output	239
Derive $\pm 15V$ and 5V from a 12V battery	240
Switch debouncer uses few parts	244

Continued on page 9

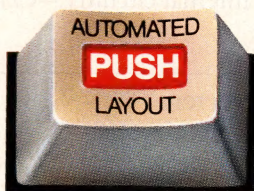
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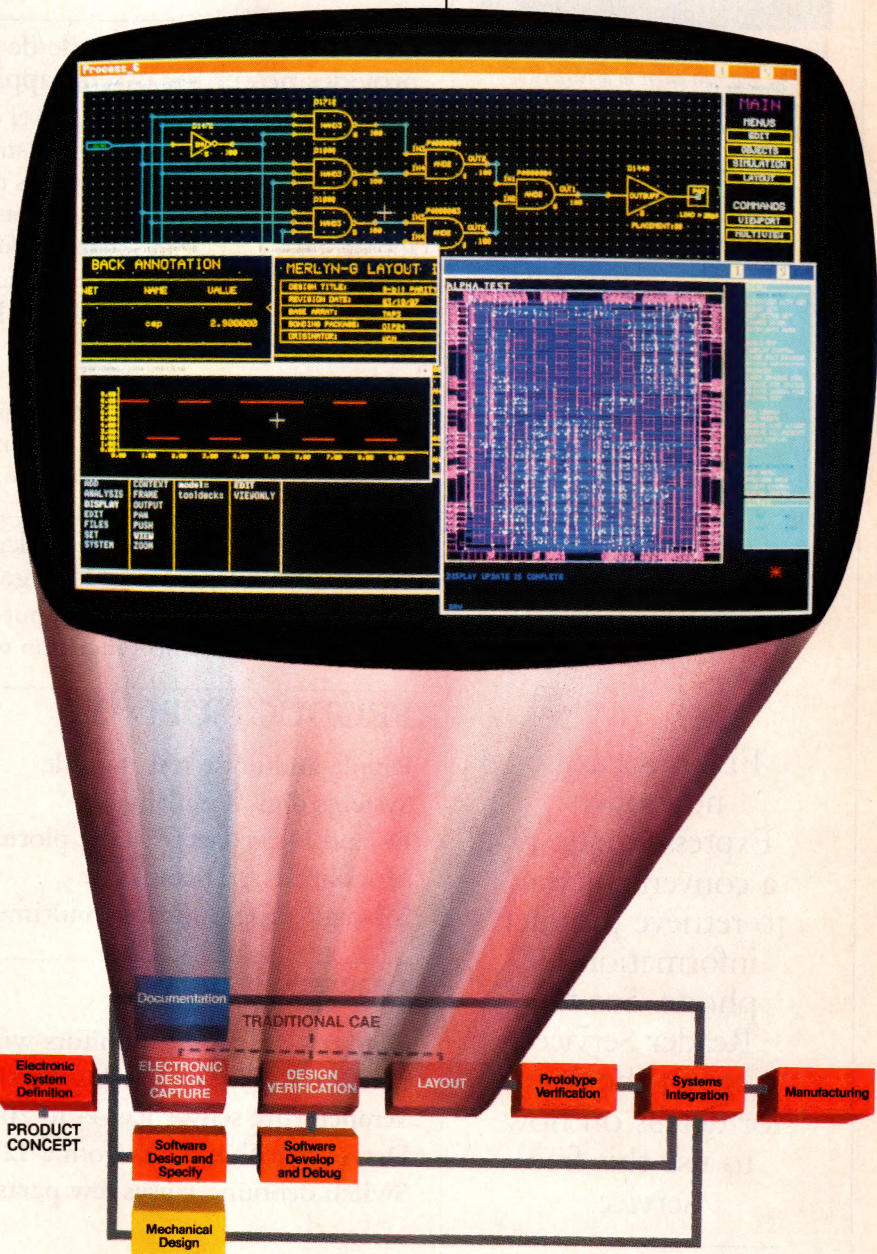
Layout so automated you can place and route a 5000-gate array 100% automatically. Just by pushing a button. With results so accurate that your layout is ASIC vendor-endorsed.

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## EDITORIAL

53

Before making assignments, be sure everyone has the proper tools and understanding to complete the jobs. Otherwise the assignments may be worthless.

## NEW PRODUCTS

Integrated Circuits .....	247
Components & Power Supplies .....	265
Computers & Peripherals .....	284
CAE & Software Development Tools .....	299
Test & Measurement Instruments .....	308

## PROFESSIONAL ISSUES

329

Change is coming for performance reviews, but it's slow and painful.—*Deborah Asbrand, Associate Editor*

## LOOKING AHEAD

341

Parallel processing spurs high-end-computer growth . . . EMI/RFI market to exceed \$8 billion by 1993.

## DEPARTMENTS

News Breaks .....	21
News Breaks International .....	24
Signals & Noise .....	32
Calendar .....	44
Readers' Choice .....	140
Leadtime Index .....	144
Business/Corporate Staff .....	315
Literature .....	324
Career Opportunities .....	332
Advertisers Index .....	340





# Only Mentor Graphics has brought a billion

more products than any other electronic design automation vendor.

# gates to light.

In just 5 years, over a billion gates have flowed through our IDEA Series™ design automation systems. And that's a very conservative estimate.

Which makes it seem all the more incredible that, before we came along, almost all electronic circuits were drafted and breadboarded by hand.

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A claim only Mentor Graphics can make. Along the way, we've pioneered schematic capture and simulation tools that are now industry standard. Like hierarchical design entry, which allows efficient management of even the largest designs. And MSPICE,™ which brings real interactivity and a graphics-oriented interface to analog simulation.

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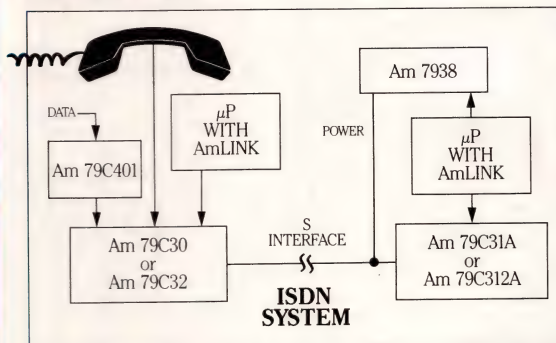
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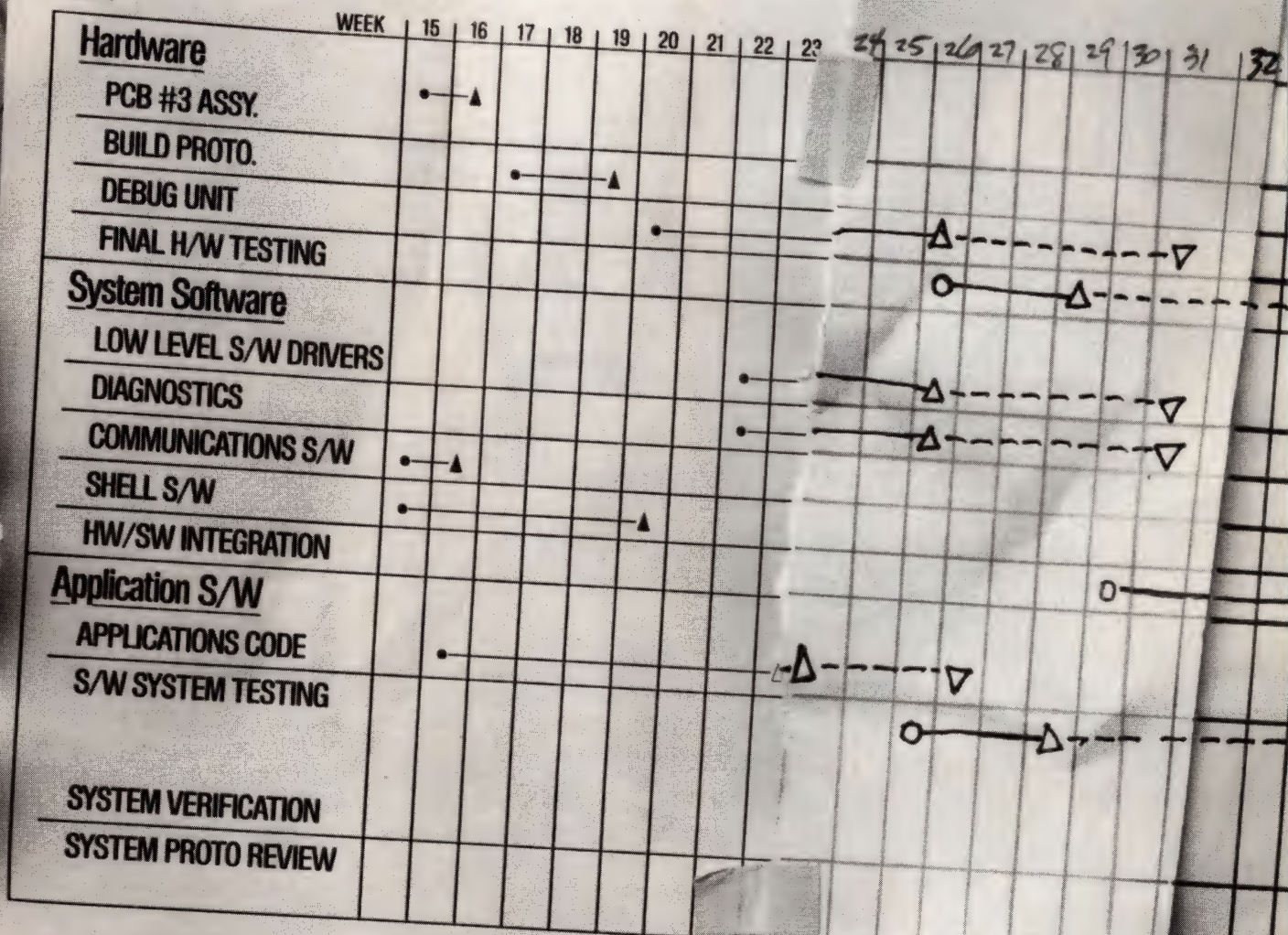
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## PRODUCT DEVELOPMENT SCHEDULE PAGE 2



Let's face it. Slipped development schedules and budget overruns can mean lost opportunities. Yet many traps that seriously delay a development schedule are quite complex, especially when they are compounded by problems that arise in cross development work.

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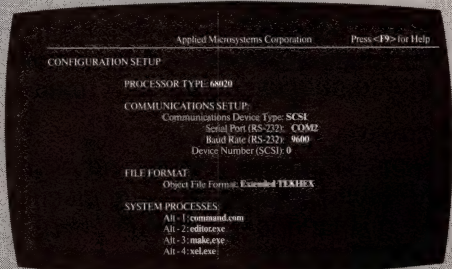
Our VALIDATE/ES DRIVER package includes easy-to-use (menu-driven and remote control) software that smoothly links the host functions to the ES 1800 emulator. This allows the upload and download of programs, symbol tables and command files.

pled with our ES 1800 emulator. You can use commands to examine variables on the fly, check contents of registers, and determine current position in code. And real-time trace is displayed as source level statements, machine instructions or bus cycles.

The packages also include a logic state analyzer probe, and provide up to 2 Megabytes of overlay memory plus full protect mode support for the 80286.

## Source Level Debugging for Motorola Microprocessors

The window-oriented VALIDATE/XEL package combines our XEL source-level debugger, a simulator and the MCC68K compiler with our ES 1800



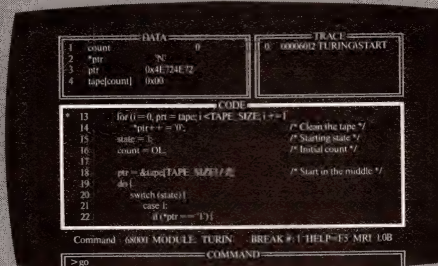
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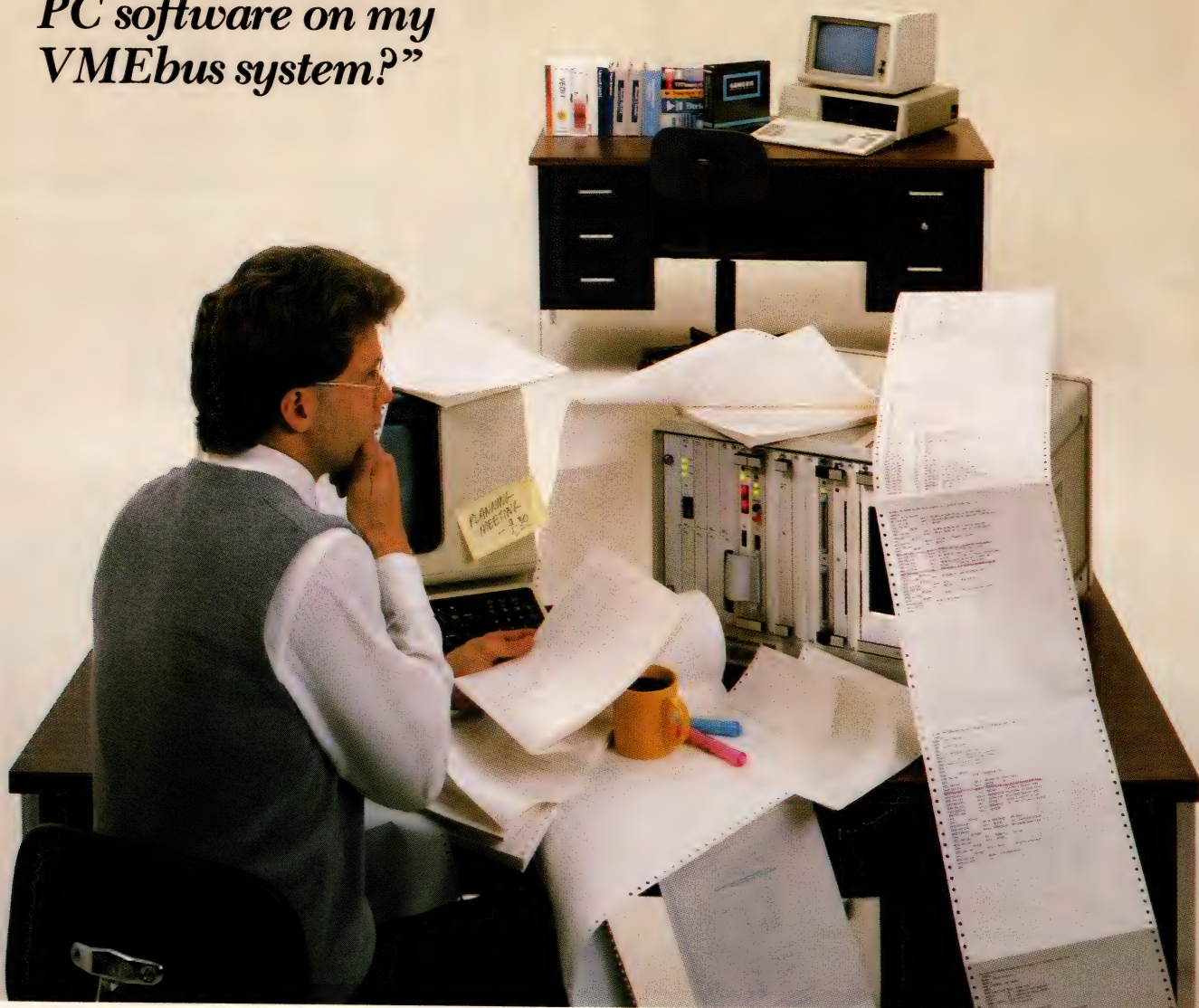
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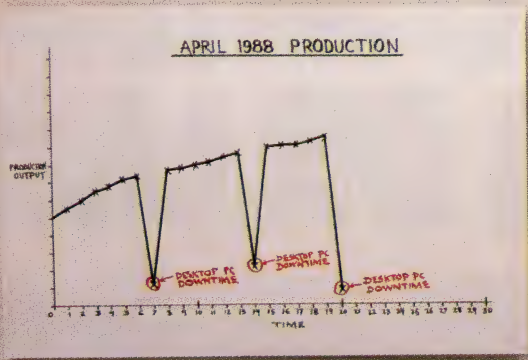
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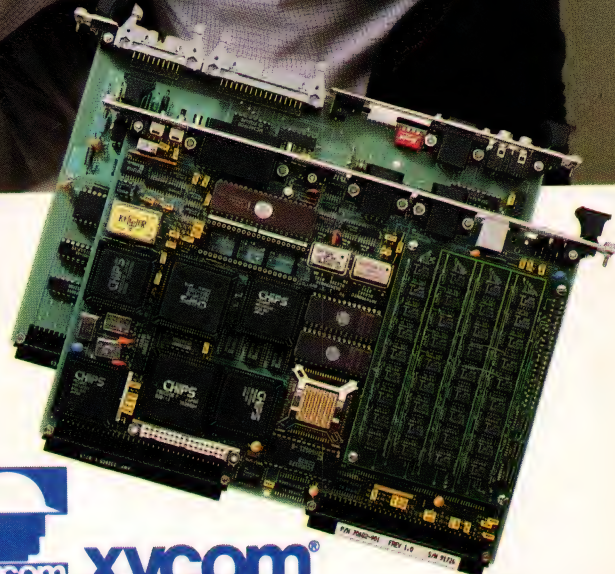


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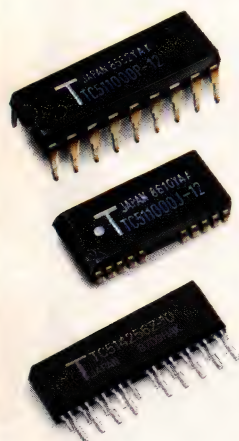
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TOSHIBA 1 Mb DRAMs					
Part Number	Organization	Process	Speed	Mode	Package
TC511000 - 85	1 Mb x 1	CMOS	85 ns	Fast Page	18 pin
TC511000 - 10	1 Mb x 1	CMOS	100 ns	Fast Page	18 pin
TC511000 - 12	1 Mb x 1	CMOS	120 ns	Fast Page	18 pin
TC511001 - 85	1 Mb x 1	CMOS	85 ns	Nibble	18 pin
TC511001 - 10	1 Mb x 1	CMOS	100 ns	Nibble	18 pin
TC511001 - 12	1 Mb x 1	CMOS	120 ns	Nibble	18 pin
TC511002 - 85	1 Mb x 1	CMOS	85 ns	Static Column	18 pin
TC511002 - 10	1 Mb x 1	CMOS	100 ns	Static Column	18 pin
TC511002 - 12	1 Mb x 1	CMOS	120 ns	Static Column	18 pin
TC514256 - 85	256K x 4	CMOS	85 ns	Fast Page	20 pin
TC514256 - 10	256K x 4	CMOS	100 ns	Fast Page	20 pin
TC514256 - 12	256K x 4	CMOS	120 ns	Fast Page	20 pin
TC514258 - 85	256K x 4	CMOS	85 ns	Static Column	20 pin
TC514258 - 10	256K x 4	CMOS	100 ns	Static Column	20 pin
TC514258 - 12	256K x 4	CMOS	120 ns	Static Column	20 pin

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TOSHIBA 256K CRAMS					
Part Number	Organization	Process	Speed	Standby Power	Package
TC55257AF-85	32K x 8	CMOS	85 ns	100µA MAX	28 pin
TC55257L-10	32K x 8	CMOS	100 ns	100µA MAX	28 pin
TC55257AL-12	32K x 8	CMOS	120 ns	100µA MAX	28 pin
TC55257AL-85L	32K x 8	CMOS	85 ns	30µA MAX	28 pin
TC55257AL-10L	32K x 8	CMOS	100 ns	30µA MAX	28 pin
TC55257AL-12L	32K x 8	CMOS	120 ns	30µA MAX	28 pin

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# NEWS BREAKS

EDITED BY JOANNE CLAY

## **SOFTWARE TOOL SIMPLIFIES SILICON-COMPILER-BASED DESIGNS**

The ChipCrafter design software from Seattle Silicon (Bellevue, WA, (206) 828-4422) provides mainstream ASIC designers with the advantages of process-independent silicon compilers. Designing for silicon compilers usually requires a custom-IC-design background that most electronics engineers and electronics companies don't have. According to the vendor, the ChipCrafter tools allow any engineer who can design a standard-cell ASIC to design a compiler-based ASIC. Compiler-based designs let you select from a variety of foundries and processes in order to optimize speed, power, and cost considerations. The software package allows you to design at the standard-cell level or lower. It also lets you create state machines and complex control circuitry from behavioral inputs. The software provides automatic placement and routing of all elements, dividing standard cells where necessary for efficient design. Because all the design elements—including the standard cells—are compiler based, you can optimize the elements on an individual basis. For example, you can adjust the size of output transistors to meet drive requirements. The package supports scan-path testing; it automatically connects all flip-flops, registers, and counters. ChipCrafter is currently in Beta-site testing; delivery of production quantities will begin in May. The package costs \$59,000.—Doug Conner

## **PARALLEL-PROCESSING COMPUTER FEATURES OPEN ARCHITECTURE**

Based on a distributed-memory, message-passing communications network, the Series 2010 parallel-processing computer from Ametek (Monrovia, CA, (818) 359-2835) lets you interface any processing node to standard VME Bus-compatible devices and local disk drives. Each node contains a 25-MHz 68020  $\mu$ P, a 68881 floating-point unit, 1M byte of local memory that's expandable to 8M bytes, and a VME Bus interface. Message passing is controlled among the nodes by automatic-message-routing devices (AMRDs) that contain five parallel channels and transfer data at speeds exceeding 20M bytes/sec. The languages available for the Series 2010 include C, Fortran 77, Unix, and Concurrent Lisp. The system uses a Sun-3 workstation as the front-end host. Pricing for the Series 2010 starts at \$45,000 for a 4-node system. Each additional node you add to the system raises the performance spec by 4 MIPS.—J D Mosley

## **DMM IC OFFERS IMPROVED CURRENT RESOLUTION**

Besides using the TSC816 digital-multimeter IC in handheld multimeters, you can use it for dedicated conversion and display of voltage, current, and resistance outputs from sensors and transducers. The DMM IC, from Teledyne Semiconductor (Mountain View, CA, (415) 968-9241), is an improvement over the earlier TSC815; it provides a 2-mA current range with 1- $\mu$ A resolution. The device has 24 operating ranges covering voltage, current, and resistance measurements. Autoranging is provided for voltage and resistance measurements. The IC has on-chip liquid-crystal-display drivers and is available in a 68-pin plastic leaded chip carrier (PLCC) for \$13.20 (100).—Doug Conner

## **LOW-COST ERASABLE-LOGIC DEVELOPMENT TOOL IS PC BASED**

The \$795 PET100 erasable-logic development system from Pistohl Electronic Tool Co (Cupertino, CA, (408) 255-2422) combines the company's \$295 erasable-logic assembler and \$495 erasable-logic programmer with a test-vector-generation language and an EPROM programmer. The assembler generates JEDEC fuse maps from your Boolean equations; a 50-rule expert system finds logic errors, suggests corrections, and pops up a WordStar-compatible editor with the cursor positioned at the error. The



# NEWS BREAKS

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erasable-logic programmer comprises programming hardware and the company's high-level test language, WIOS. The system supports EEPLDs from Altera, Atmel, Cypress, AMI/Gould, ICT, and Monolithic Memories.—Margery S Conner

## **SIGNAL PROCESSOR COMES IN 10- AND 12.5-MHz VERSIONS**

The ADSP-2100 digital-signal processor from Analog Devices (Norwood, MA, (617) 461-3881) is now available in 10- and 12.5-MHz versions (the ADSP-2100AJ and -2100AK, respectively). The vendor claims the product's speed and architectural efficiency make it the industry's fastest general-purpose DSP chip. According to the company, the ADSP-2100A can compute an in-place, complex 1024-point FFT in 3.0 msec, a speed comparable to that of dedicated FFT chips. The -2100AJ and -2100AK are code and pin compatible with the company's earlier 6- and 8-MHz (-2100J and -2100K) versions of the chip, and are available in 100-lead pin-grid arrays and 100-lead PLCCs. The 10- and 12-MHz chips, in PLCCs, cost \$103 and \$133 (1000), respectively; samples are available from stock. The vendor plans to introduce a military-temperature version of the 10-MHz chip in the fourth quarter of 1988. The company also offers a C compiler that generates source assembly code for the 2100 and 2100A chips. The compiler conforms to the ANSI X3J11 draft, and it comes in MS-DOS, VAX/VMS, and Unix BSD 4.2 versions. Emulators and evaluation boards for the -2100A chips will be available in the second quarter of 1988.—Joanne Clay

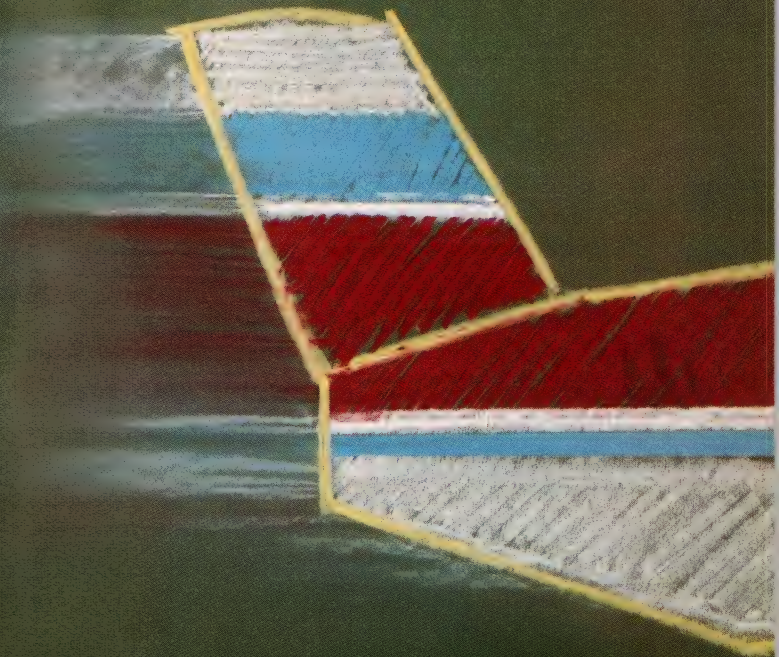
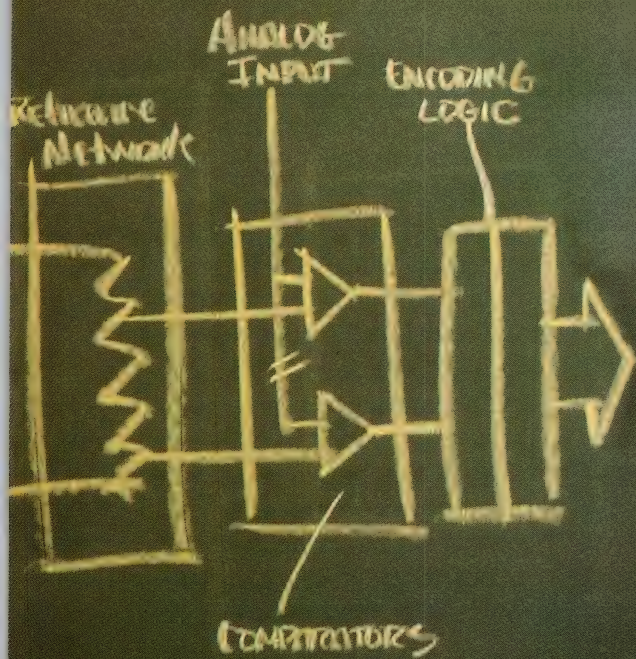
## **INEXPENSIVE DIGITAL-FILTERING SOFTWARE RUNS ON YOUR PC**

You can now purchase an integrated data-acquisition, -storage, and -analysis software package that also provides four types of digital filters: lowpass, highpass, bandpass, and band reject. The \$1185 package includes a data-acquisition program called Snapshot Storage Scope, the Snap-Calc analysis and monitoring program, and the new Snap-Filter program. The software was developed by HEM Data Corp (Southfield, MI, (313) 559-5607). If you already have the Snap-Calc and Snapshot Storage Scope programs, you can buy Snap-Filter for \$395. Snap-Filter lets you specify any filter as a finite-impulse-response or infinite-impulse-response filter. To order a demonstration disk, contact Andrea Tomaszewski at the above number.—J D Mosley

## **OPTION BOOSTS LASER-PROCESSING SYSTEM'S THROUGHPUT BY 15%**

By adding the H844 vision-processing option to the M218 Laser Processing System from Teradyne's Industrial Consumer Div (Boston, MA, (617) 482-2700, TWX 710-321-1055), you can boost the system's throughput by 15% and improve its wafer-alignment success rate to better than 99.99%, the vendor claims. With the H844 option, the M218 system performs high-speed wafer alignment by using proprietary vision algorithms. The H844's user interface includes software windows, a mouse, pull-down menus, and graphics tools. The H844 is also available with an optical-character-recognition feature, which reads alphanumeric characters printed on the wafer in standard fonts. The M218 system incorporates a Unix-based Sun workstation, a digital-signal processor, an automatic-calibration facility, and an Ethernet interface. It performs precise link-cutting operations on a variety of silicon devices, including dynamic and static RAMs and gallium arsenide ICs. The H844 vision-processing option costs \$40,000; the optional optical-character-recognition feature is \$20,000. Delivery is 16 weeks ARO.—Joanne Clay





## THE COMPETITION IS STILL TALKING ABOUT THEIR 10-BIT FLASH ADC

That's right — shipping. For years there's been a lot of talk about monolithic 10-bit ADCs. The talk is over. The TDC1020 is a reality. The world's first monolithic 10-bit flash ADC is available from TRW LSI Products.

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# NEWS BREAKS: INTERNATIONAL

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## **SINGLE-BOARD Q BUS COMPUTERS RUN PDP-11 SOFTWARE**

Featuring a DEC J-11 processor that has zero-wait-state access to as much as 4M bytes of parity-checked onboard dynamic RAM, the M80 and M90 quad Q Bus single-board computers from Mentec Computer Systems Ltd (Dublin, Ireland, TLX 93309) can run unmodified DEC PDP-11 operating systems and software. The M80's 15-MHz processor provides a 30% improvement in speed over the company's earlier M70 single-board computer; the M90's 18.5-MHz processor provides a 60% speed improvement over the M70. The M80 and M90 each offer four serial-I/O ports, 32k bytes of bootstrap EPROM, and an EEPROM that allows you to configure the board. The software-configurable boot program can step through as many as six different bootstrap calls, allowing you to use the board as a host processor in a variety of system configurations. The M80 will be available in OEM quantities by March 1988; a 1M-byte version costs £2500 (50). The M90 will be available by May 1988. A 4M-byte version of the M90 sells for £5150 (50).—Peter Harold

## **LOW-COST LOGIC ANALYZER PROVIDES 32-CHANNEL, 25-MHz OPERATION**

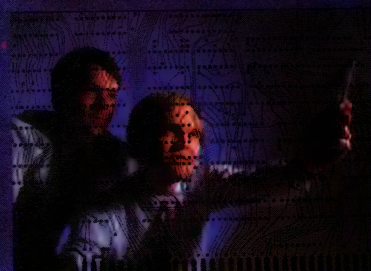
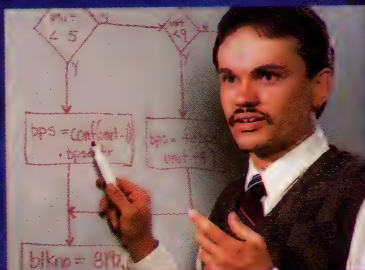
Priced at £1790, the TA1000 logic analyzer from Thandar Electronics Ltd (St Ives, UK, TLX 32250) provides you with 32 state/timing channels that operate at 25 MHz. The instrument's trace memory amounts to 1k bits/channel, and its external clock facilities include three independent clock inputs and five clock qualifiers. You can define as many as four 32-bit trigger/restart words, which you can logically OR together in each step of a 4-step trigger sequencer. Each step of the trigger sequencer also includes a 1- to 256-event counter. You can display timing or variable-format state information on the analyzer's 7-in. CRT, and you can analyze the information by using the instrument's trace-expansion facilities, its two screen cursors, and its reference memory. You can also perform automatic trace/reference-memory comparisons on any portion of the traced data. An optional feature lets you stop trace acquisition on trace/reference equality or inequality, or count the occurrences of these conditions. The instrument's price includes IEEE-488 and RS-232C control interfaces. Variable-threshold input pods and disassemblers for 8- and 16-bit  $\mu$ Ps are available as options.—Peter Harold

## **FIRMS PRODUCE FIRST TRON-BASED 32-BIT $\mu$ P AND PERIPHERALS**

Hitachi, Fujitsu, and Mitsubishi have developed the first 32-bit microprocessor and peripheral chips based on the Tron architecture proposed by professor Ken Sakamura of Tokyo University. The chips are the result of the three firms' agreement to develop Tron  $\mu$ Ps and peripheral circuits in three stages. Hitachi's development is the GMicro/200 32-bit  $\mu$ P, which runs at 20 MHz and can perform 6 MIPS. The chip has sixteen 32-bit registers and can manage as much as 4G bytes of data. Hitachi manufactures the chip with a 1- $\mu$ m CMOS double-layer-aluminum process. The device measures 14×14 mm and incorporates approximately 730,000 transistors. Samples of the chip will be available this spring; Hitachi will begin mass production of the device in the fall of 1988. Fujitsu plans to develop a 12- to 20-MIPS version of the GMicro/200 by the end of 1988, and Mitsubishi is scheduled to develop a 4.5- to 10-MIPS version by the first half of 1989. Fujitsu has also developed three peripheral ICs for the 32-bit  $\mu$ P: They include a DMA controller that can receive and send data at 27M bytes/sec without using the  $\mu$ P, a tag memory with a 27-nsec readout speed, and an interrupt controller.—Joanne Clay



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Despite its extremely tiny size, only 0.185 by 0.185 by 0.06 in., these switches provide 50dB isolation (considerably higher than many larger units) and insertion loss of only 1dB. The absorptive model KSWA-2-46 exhibits a typical VSWR of 1.5 in its "OFF" state over the entire frequency range. These surface-mount units can be soldered to pc boards using conventional assembly techniques. The KSW-2-46, priced at only \$32.95, and the KSWA-2-46, at \$48.95, are the latest examples of components from Mini-Circuits with unbeatable price/performance.

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### SPECIFICATIONS

	<b>KSW-2-46</b> <b>ZFSW-2-46</b>		<b>KSWA-2-46</b> <b>ZFSWA-2-46</b>	
FREQ. RANGE	dc-4.6 GHz		dc-4.6 GHz	
INSERT. LOSS (db)	typ	max	typ	max
dc-200MHz	0.9	1.1	0.8	1.1
200-1000MHz	1.0	1.3	0.9	1.3
1-4.6GHz	1.3	1.7	1.5	2.6
ISOLATION (dB)	typ	min	typ	min
dc-200MHz	60	50	60	50
200-1000MHz	45	40	50	40
1-4.6GHz	30	23	30	25
VSWR (typ)	ON	1.3:1	1.3	
	OFF	—	1.4	
SW. SPEED (nsec)				
rise or fall time	2(typ)		3(typ)	
MAX RF INPUT (bBm)				
up to 500MHz	+17		+17	
above 500MHz	+27		+27	
CONTROL VOLT.	-5V on, OV off		-5V on, OV off	
OPER/STOR TEMP.	-55° to +125°C		-55° to +125°C	
PRICE (1-24)	<b>\$32.95</b> <b>\$72.95</b>		<b>\$48.95</b> <b>\$88.95</b>	

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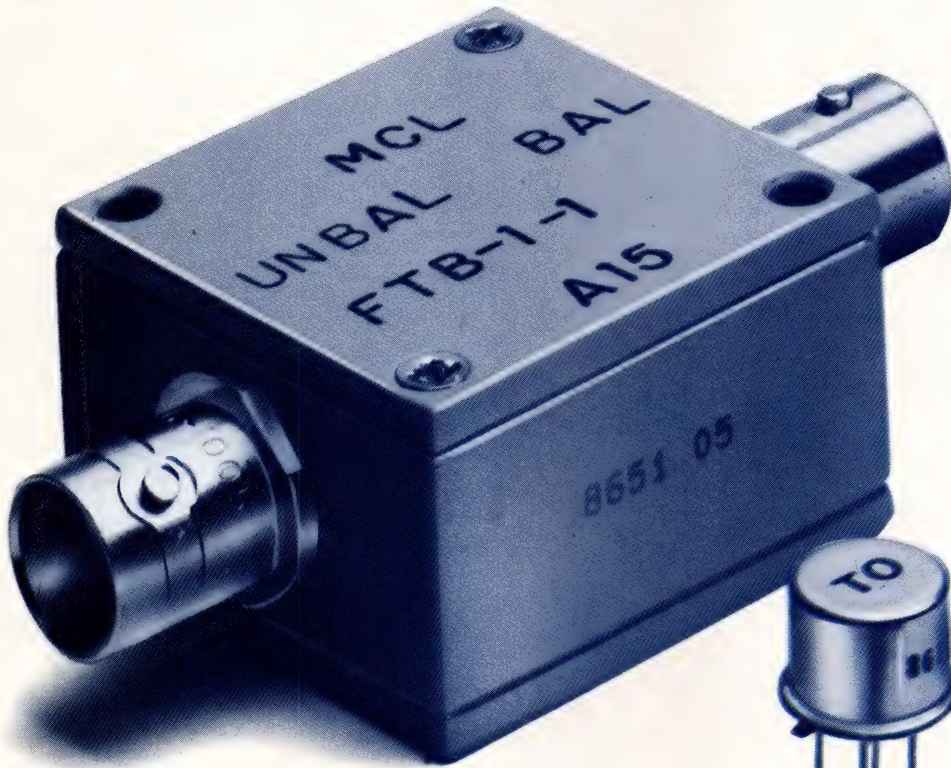
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EDN February 18, 1988



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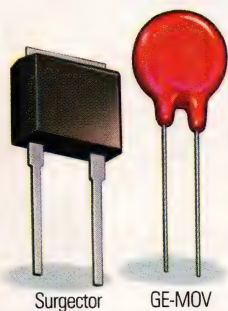
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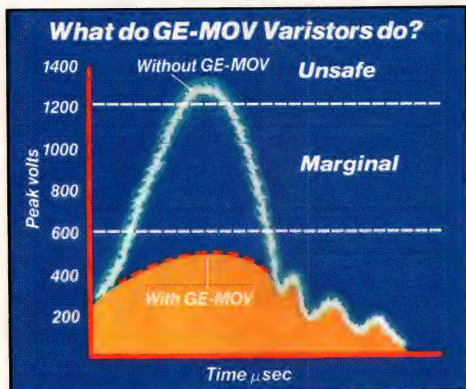


Now, whether you're designing small consumer products, industrial controls, high-rel military and aerospace systems, or anything in between, we have a surge protection solution for you. Because if one of our GE-MOV varistors isn't exactly right for the job, then one of our Surgectors probably will be.

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They're available in a variety of packages, including axial leaded, radial leaded, leadless surface mount, high-energy modules and connector-pin configurations. And they're all available for fast delivery.

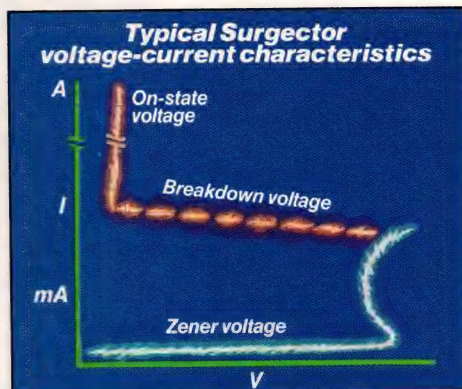
### Inventor of Surgector devices.

Surgector devices respond rapidly and handle a lot of energy. So they're ideal for protecting

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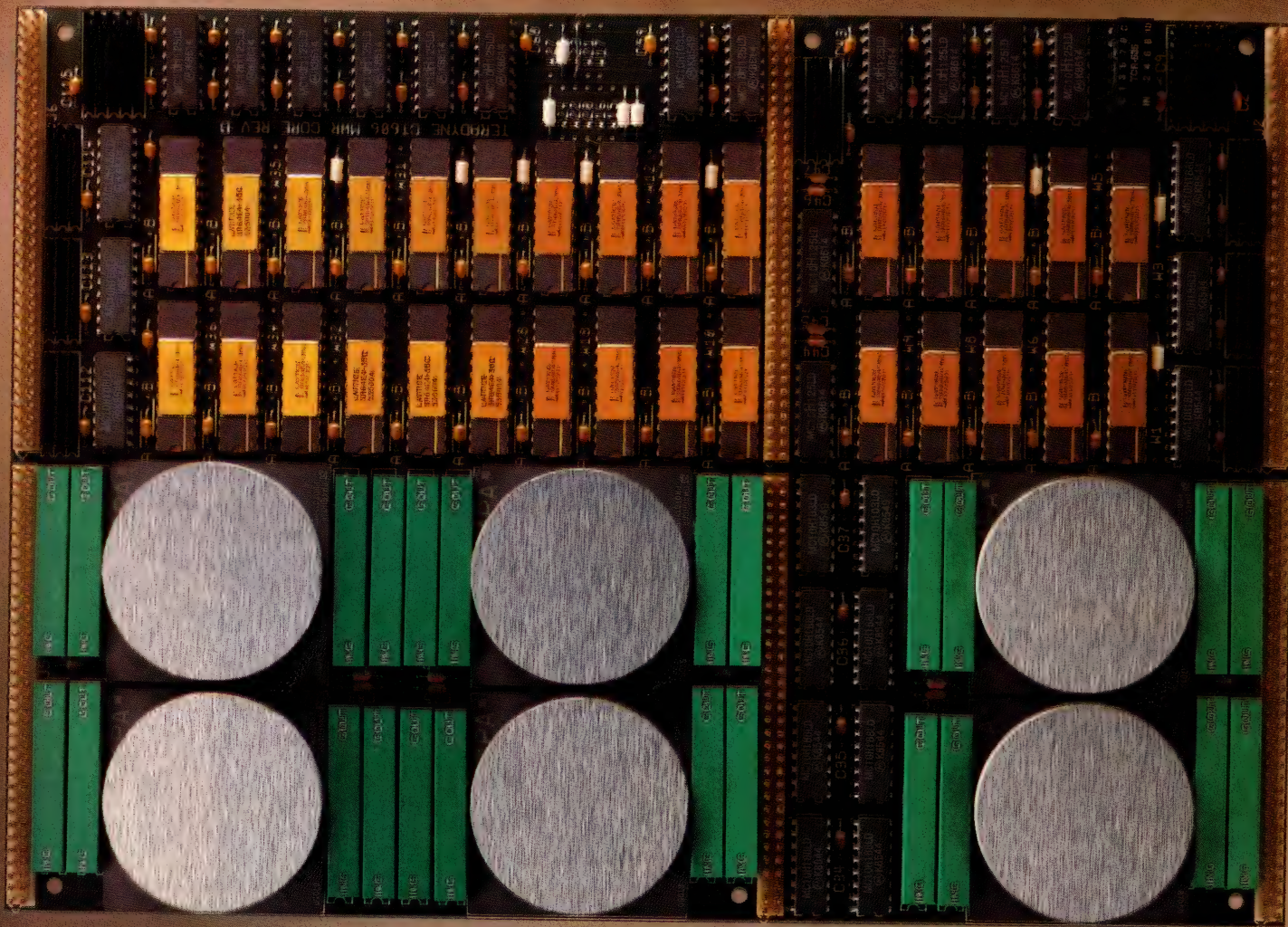


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# If you're testing complex boards

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Start with the most advanced hardware for analog and digital testing. An L200 fires functional test patterns at 40 MHz rates. At up to 1152 test channels. Top speed is 80 MHz. That's 4 to 8 times faster than any competitor can deliver.

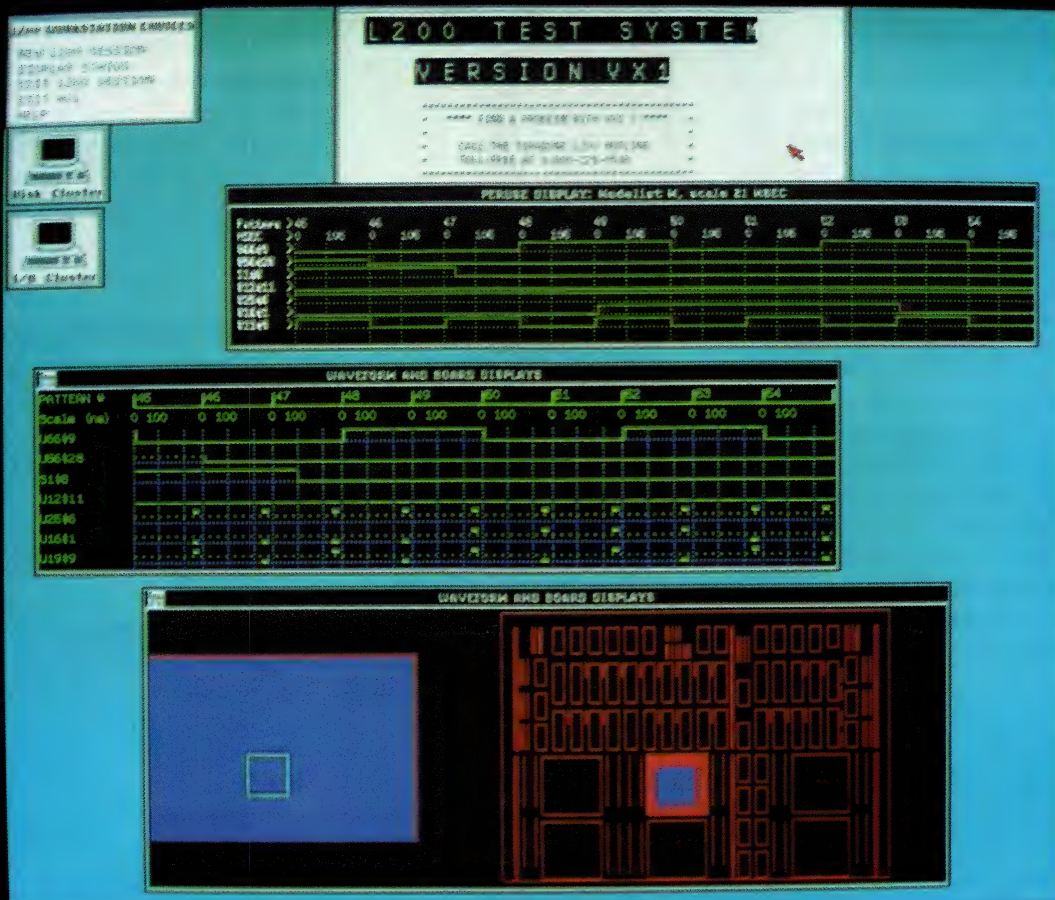
And the L200 hits test signal timing precisely. With up to 32 timing sets for drive phases and test windows. Its 250 ps programming resolution with zero dead time puts signal edges right where you want them.

## Divide and conquer.

VLSI/VHSIC boards demand large, complex test programs. But the L200's distributed computer architecture simplifies matters.

Testing is controlled by a VAX computer. It sends tasks to specialized processors for rapid deployment of analog, digital, and memory tests.





# here's a simple plan of attack.

Programmers will appreciate clustered VAX workstations. Graphics, like waveforms and shmoo plots, make heavy debug and analysis light work.

## Simulation and other tactics.

High-powered software tools tailor L200 test development to modern design techniques and test

	Test Channels	Maximum Pattern Rate	Channel Skew
L297	1152	80 MHz	± 1.5 ns
L293	576	80 MHz	± 1.5 ns
L280vx	1152	10 MHz	± 10 ns
L210vx	576	10 MHz	± 10 ns

L200 VLSI board test systems are the performance leaders.

Take our LASAR simulator. It works closely with the L200 for both cluster and board-level testing. LASAR accurately predicts VLSI circuit responses and reports test program fault coverage.

Significantly, LASAR simulates L200 characteris-

strategies. Precisely the caliber of tools you need to get tests up and running fast.

tics. So test programs automatically include when to test board responses. And what response is expected. The result is uncompromising go/no go tests as well as precise guided probe or fault dictionary diagnosis.

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L200's have proven themselves under fire at hundreds of advanced manufacturing sites worldwide. So if you're about to take on a new VLSI/VHSIC project, find out how to launch a winning test strategy. Call your local Teradyne sales office or write:

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# SIGNALS & NOISE

## Getting back to basics

The December 10, 1987, article, "An experimental graduate-engineering program opens up new study opportunities" (Professional Issues, pg 363), brings up another problem that is contributory to the one that concerns Daniel Sternlicht.

The level of education available to average high-school students deprives them of the broad base of knowledge that they need to build on in lower-level college classes. In a state that has a high functional-illiteracy rate and that boasts a high-school curriculum whose only required subjects are physical education and English, there's no chance that a high-school graduate can carry a college course load sufficient to complete an engineering degree in the allocated four years of 16-credit semesters.

The education available to me (Central High School, Philadelphia,



PA, class of 1941) can't be duplicated now in any public school system dedicated to passing substandard students through a watered-down system where baseball is more important than biology, and Latin is passed over for linebackers.

If it takes two years in a junior college to achieve the level of education sufficient to tackle a technical

college course such as engineering, then, perforce, an advanced degree will be mandatory in that area, especially where licensing is required.

*Richard La Porte*

*Engineered Magnetics Inc  
Hawthorne, CA*

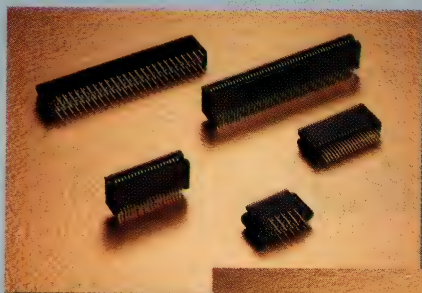
## As manufacturing goes, so goes the service sector?

Your December 10, 1987, editorial (pg 53) on the service-economy myth was excellent. Other articles show economists are now beginning to realize that service firms are not the salvation for this country.

Although you mentioned the service sector's low pay and poor job security, you left out the most glaring weakness of the service economy: Service firms such as law and accounting firms depend on the manufacturing sector.

If manufacturing falls flat on its

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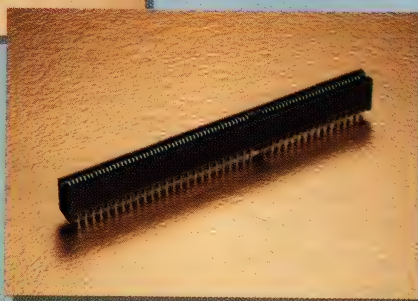
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Now SEEQ offers superfast E<sup>2</sup>s that are right on target for avionics control-store applications — or any system where high-performance graphics, array processing or DSP are essential. With access times as low as 35 ns, SEEQ's CMOS E<sup>2</sup>s deliver performance that's unmatched by other EEPROMs.

That means now you're no longer up in the air for fast, non-volatile memory solutions. Among your current options, bipolar PROMs give you speed, but they're gas-guzzlers when it comes to power. And a little hard to re-program when your product's not in the shop. By comparison, SEEQ 16K and 32K E<sup>2</sup>s offer equivalent speeds, but consume less than *half the power*. So they can run with no-wait-state microprocessors — without running up your costs for power supplies and cooling equipment.

Your other alternative — slower E<sup>2</sup>s with battery-backed static RAMs — usually can't keep up the pace in high-performance systems. And they complicate your design, because you need to constantly load and unload RAM for program execution. Again, SEEQ E<sup>2</sup>s resolve these speed/power dilemmas, while simplifying your designs. Plus their read/write cycles look just like a SRAM's, so they're easy to incorporate into your existing systems.

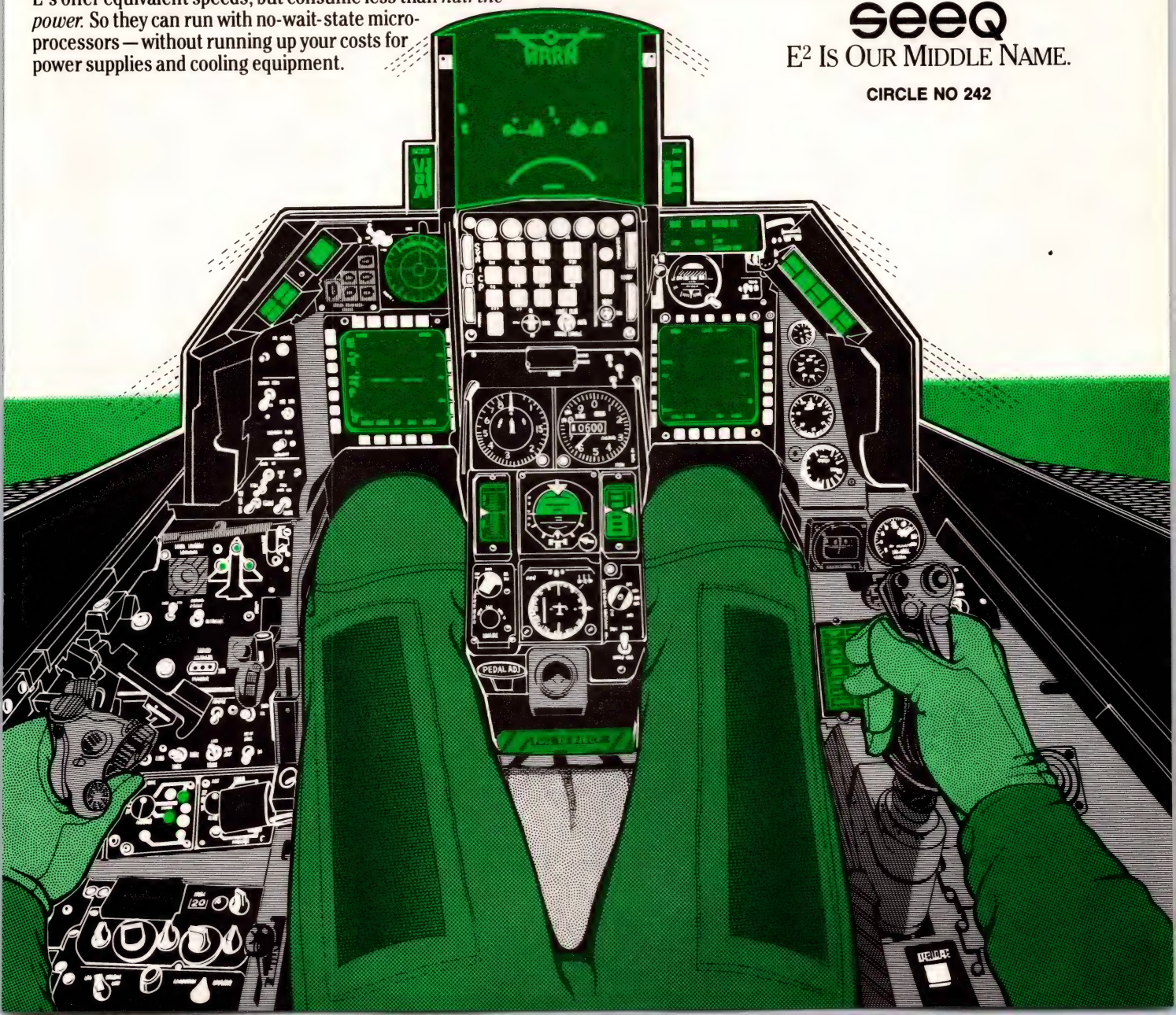
All of which makes SEEQ E<sup>2</sup>s the only way to fly.

At SEEQ, we can help you with virtually *any* non-volatile memory application — from high-density E<sup>2</sup>s to microcomputers with E<sup>2</sup> on board. For information on the uses of our high-speed commercial or military E<sup>2</sup>s, call us today for our Application Note #27. SEEQ Technology, Inc., 1849 Fortune Drive, San Jose, CA 95131. (408) 432-9550.

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## SIGNALS & NOISE

face, service firms will come tumbling down. When service firms automate with computers to the extent that manufacturers already have, the layoffs that manufacturers are famous for will be nothing compared to the bloodbath we can expect in the service sector.

Glen Spielbauer,  
Dallas, TX

### MLL: Medium-level language

The article entitled "HLL cross compilers speed 1-chip- $\mu$ C software development" (EDN, December 24, 1987, pg 126) omitted all mention of Forth. Forth has been the high-level language of choice for microcontroller projects almost since the day they first came out. The only reason I can think of that regional editor Steve Leibson left Forth out of his article is that he is one of those ill-informed computer-language snobs who doesn't consider Forth a "real" high-level language.

Robert Johnson  
Friedhoff Control Co  
Duluth, MN

*(Ed Note: Steve Leibson says he isn't an ill-informed computer-language snob. His research for the article uncovered no Forth languages for a single-chip computer. He'd like to hear from readers who know of any.)*

### Correction

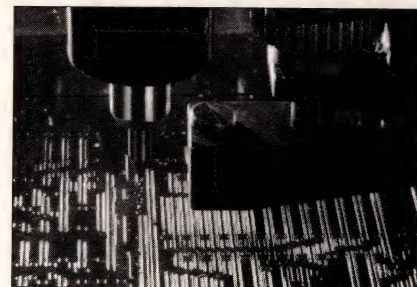
In the schematic for the Design Idea "Circuit protects solenoids in dot printer" (EDN, December 10, 1987, pg 325), IC<sub>6A</sub> pins 1 and 2 should be connected to ground.

### WRITE IN

Send your letters to the Signals and Noise Editor, 275 Washington St, Newton MA 02158. We welcome all comments, pro or con. All letters must be signed, but we will withhold your name upon request. We reserve the right to edit letters for space and clarity.

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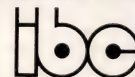
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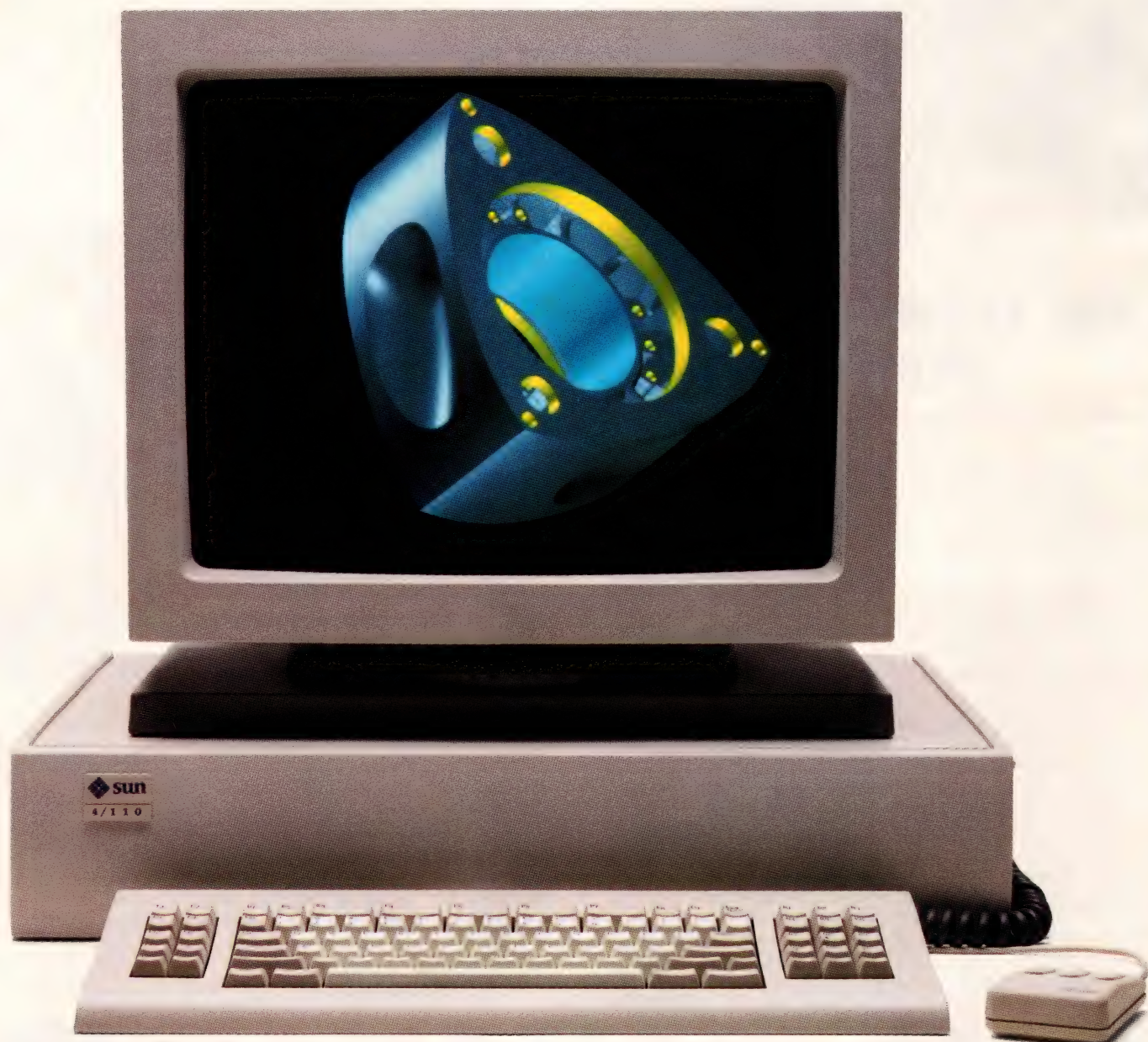
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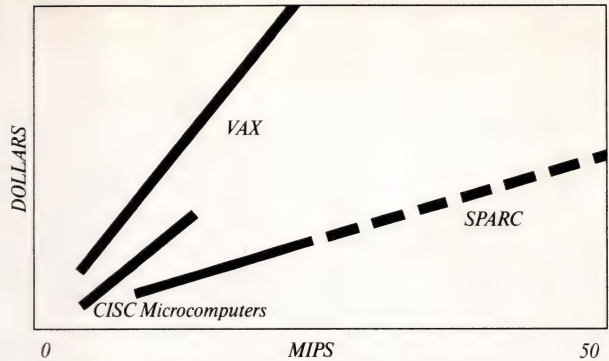
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Motorola's just taken a quantum leap in simplifying ASIC designs. Our new cell compilers let you set the parameters and priorities of over 20 different cells to your exact specifications, without compromise and without settling for *something pretty close*.

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All Motorola silicon compilers are layout rule independent. They can be used in today's designs and, as the technology advances to make even smaller geometries possible, they'll continue to support your efforts without becoming obsolete.

Data path compilers	Functional Blocks
<ul style="list-style-type: none"><li>• Latch</li><li>• D-Register</li><li>• Comparator</li><li>• 3-State Buffer</li><li>• Counter</li><li>• Adder</li><li>• Multiplexer</li><li>• Register File 1R/W</li><li>• Register File 2R/1W</li></ul>	<ul style="list-style-type: none"><li>• ALU</li><li>• Barrel Shifter</li><li>• Incrementer/Decrementer</li><li>• Parity Gen/Checker</li><li>• Inverter</li><li>• Serial Interface (SPI function)</li><li>• I/O Port</li><li>• PLA</li><li>• Prescaler</li><li>• RAM</li><li>• ROM</li><li>• Status/Control Register</li><li>• Timer</li><li>• UART (SCI function)</li></ul>

### How it works.

The menu-driven system makes it easy for anyone to use, simply select the function you need and go. Through schematic entry, input the parameters for the cell

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# CALENDAR

**Microwave IC Technology** (seminar), Fullerton, CA. California State University, Office of Extended Education, Fullerton, CA 92634. (714) 773-3080. March 4.

**Personal Computer Interfacing for Scientific Instrumentation Automation** (short course), Blacksburg, VA. Linda Leffel, CEC, Virginia Tech, Blacksburg, VA 24061. (703) 961-4848. March 10 to 12.

**Modern Electronic Packaging** (seminar), San Diego, CA. Technology Seminars, Box 487, Lutherville, MD 21093. (301) 269-4102. March 15 to 17.

**Microelectronic Packaging and Surface Mounting** (seminar), Fullerton, CA. California State University, Office of Extended Education, Fullerton, CA 92634. (714) 773-3080. March 18.

**10th Annual Conference for Inventors and Entrepreneurs**, Denver, CO. Rocky Mountain Inventors Congress, Box 4365, Denver, CO 80204. (303) 443-3818. March 18 to 19.

**Neural Networks for Artificial Intelligence**, Arlington, VA. Technology Transfer Institute, 741 10th St, Santa Monica, CA 90402. (213) 394-8305. March 21 to 23.

**Digital Signal Microprocessor and Microcomputer Chips and Development Systems** (seminar), Cambridge, MA. Amnon Aliphas, DSP Associates, 18 Peregrine Rd, Newton, MA 02159. (617) 964-3817. April 4 to 6.

**Microcircuit Interconnections and Assembly Methods** (seminar), Fullerton, CA. California State University, Office of Extended Education, Fullerton, CA 92634. (714) 773-3080. April 7.

**Electrostatic Discharge (ESD): Concern or Over-concern?** (seminar),

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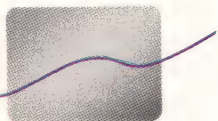
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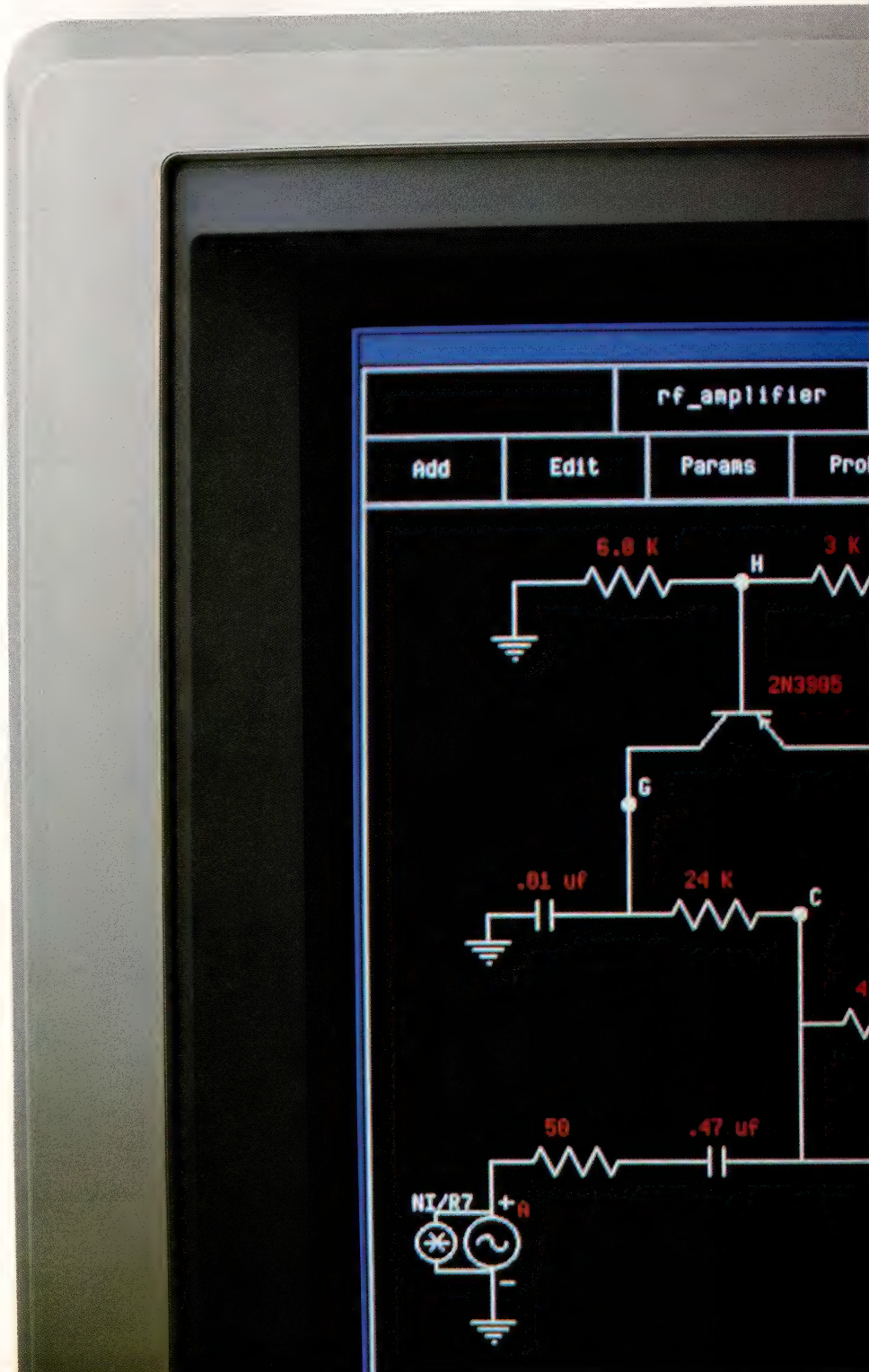
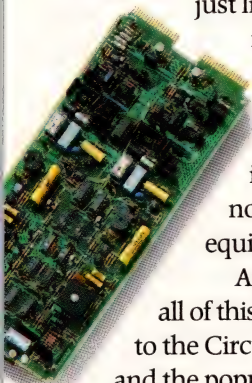
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CIRCLE NO 18

## CALENDAR

nar), Fullerton, CA. California State University, Office of Extended Education, Fullerton, CA 92634. (714) 773-3080. April 12.

**Hybrid Microcircuit Technology** (seminar), Fullerton, CA. California State University, Office of Extended Education, Fullerton, CA 92634. (714) 773-3080. April 18.

**American Power Conference**, Chicago, IL. Robert Porter, Chicago Institute of Technology, Chicago, IL 60618. (312) 567-3202. April 18 to 20.

**Instrument Society of America/IEEE Columbus Conference and Exhibit**, Columbus, OH. Sol Black, AT&T Network Systems, Dept 11CB123430, 6200 E Broad St, Columbus, OH 43213. (614) 860-5605. April 19 to 20.

**IEEE Instrumentation/Measurement Technology Conference** (IMtc/88), San Diego, CA. Bob Myers, IMtc, 1700 Westwood Blvd, Los Angeles, CA 90024. (213) 475-4571. April 19 to 22.

**Modern Electronic Packaging** (seminar), Raleigh, NC. Technology Seminars, Box 487, Lutherville, MD 21093. (301) 269-4102. April 20 to 22.

**Modern Microwave Techniques** (short course), Los Angeles, CA. UCLA Extension, 10995 Le Conte Ave, Los Angeles, CA 90024. (213) 825-3344. April 25 to 28.

**Pittsburgh Conference on Modeling and Simulation**, Pittsburgh, PA. William Vogt or Marlin Mickle, 348 Benedum Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15261. May 5 to 6.

**EMC Expo**, Washington, DC. Karen Smith, EMC Expo, Box D, Gainesville, VA 22065. (703) 347-0030. May 10 to 12.



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All your SRAM systems can be "go" today, with Saratoga's BiCMOS

parts. Besides our 64K TTL line, we're shipping volume orders of our 4K and 16K TTL families, plus ECL SRAMs in 4K and 16K densities. These parts feature speeds as fast as 8 nsec, and full military temperature range operation.

So if you're not sure whether those other fast SRAMs are coming or going, check Saratoga. Call (408) 864-0500 today, or write Saratoga Semiconductor, 10500 Ridgeview Court, Cupertino, CA 95014.

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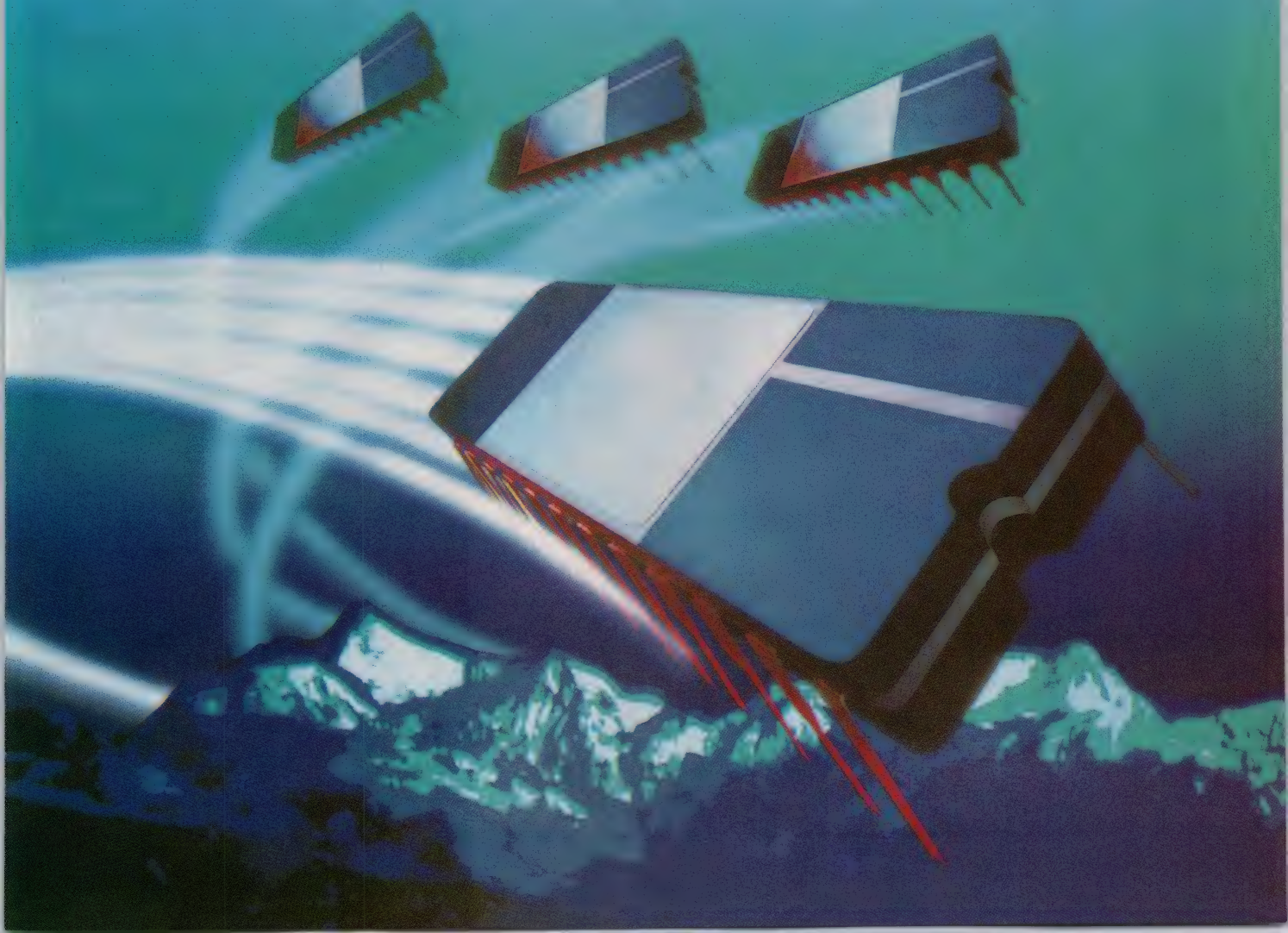
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Ever seem like your CAE and CAD people are playing for different teams? Especially when it's time to turn that hot new system design into a working board?

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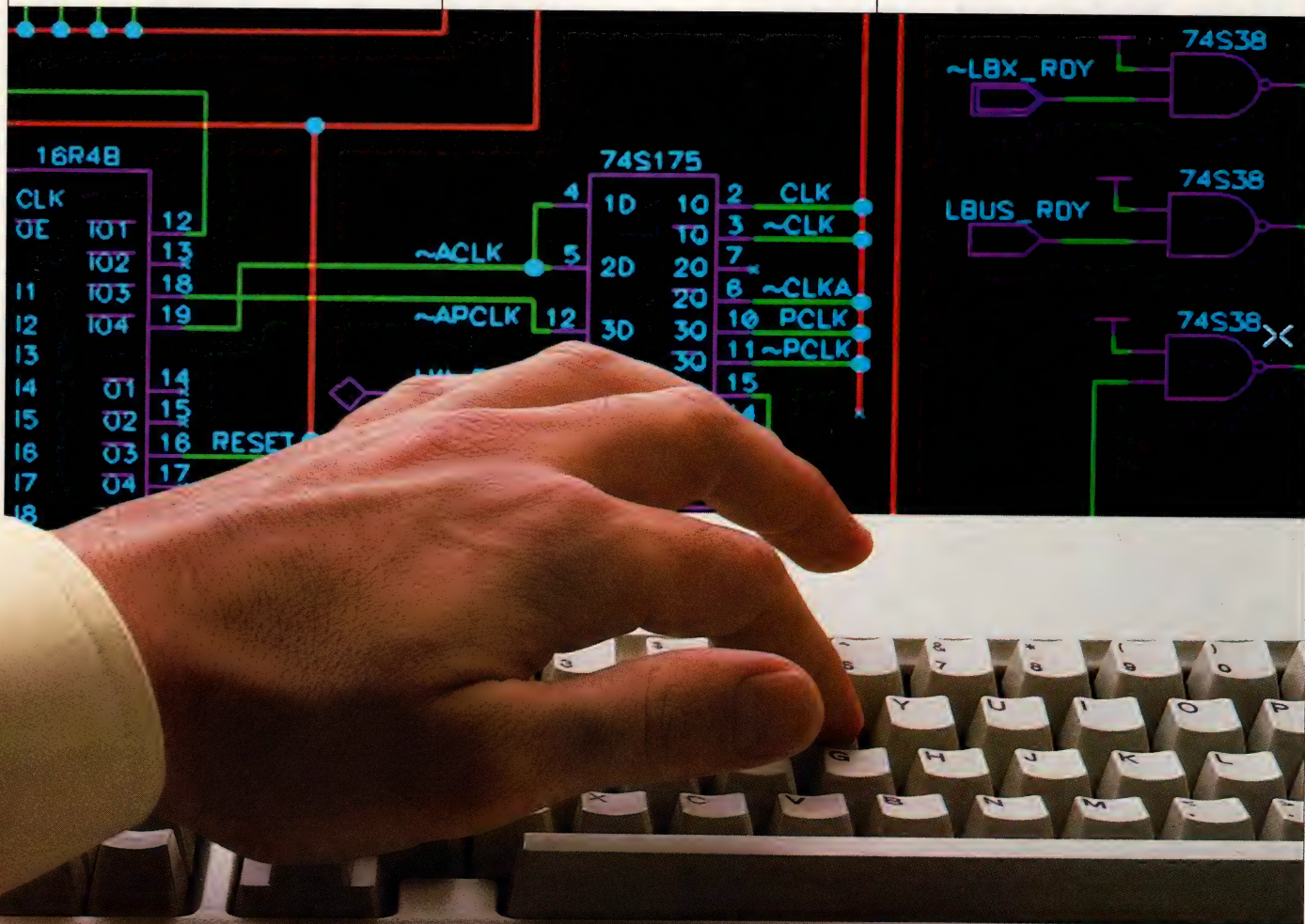
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With these rules guiding the process, layout designers can concentrate on maximizing the quality and manufacturability of the layout without having to second-guess the engineer's real intentions.

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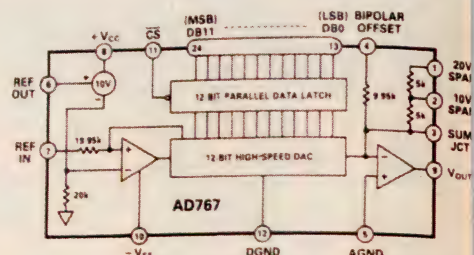


## Fast Interface 12-Bit D/A Converter

### AD767

#### FEATURES

Complete 12-Bit D/A Function  
On-Chip Output Amplifier  
High Stability Buried Zener Reference  
Fast 40ns Write Pulse  
Guaranteed for Operation with  $\pm 12\text{V}$  or  $\pm 15\text{V}$  Supplies  
0.3" Skinny DIP Package



AD767 Functional Block Diagram

#### PRODUCT DESCRIPTION

The AD767 is a complete voltage output 12-bit digital-to-analog converter including a high stability buried zener reference and input latch on a single chip. The converter uses 12 precision high-speed bipolar current steering switches and a laser-trimmed thin-film resistor network to provide high accuracy.

Microprocessor compatibility is achieved by the on-chip latch. The design of the input latch allows direct interface to 12-bit buses. The latch responds to strobe pulses as short as 40ns, allowing use with the fastest available microprocessors.

The functional completeness and high performance of the AD767 result from a combination of advanced switch design, high-speed bipolar manufacturing process, and proven laser wafer-trimming (LWT) technology.

The subsurface (buried) zener diode on the chip provides a low-noise voltage reference which has long-term stability and temperature drift characteristics comparable to the best discrete reference diodes. The laser trimming process which provides the excellent linearity is also used to trim the absolute value of the reference as well as its temperature coefficient. The AD767 is thus well suited for wide temperature range performance with  $\pm 1/2\text{LSB}$  maximum linearity error and guaranteed monotonicity over the full temperature range. Typical full-scale gain T.C. is 5ppm/ $^{\circ}\text{C}$ . The AD767 is packaged in a small, 0.3" wide, 24-pin DIP.

#### PRODUCT HIGHLIGHTS

1. Complete 12-bit DACPORT<sup>TM</sup>.  
The AD767 is a complete voltage output DAC with voltage reference and digital latches on a single IC chip.
2. The input latch responds to write pulse widths as short as 40ns assuring direct interface with the industry's fastest microprocessors.
3. The internal buried zener reference is laser trimmed to 10.00 volts with a  $\pm 1\%$  maximum error. The reference voltage is also available for external application.
4. The gain setting and bipolar offset resistors are matched to the internal ladder network to guarantee a low gain temperature coefficient and are laser trimmed for minimum full-scale and bipolar offset errors.
5. The precision high-speed current steering switches and on-board high-speed output amplifier settle within  $1/2\text{LSB}$  for a 10V full-scale transition in 3.0 $\mu\text{s}$  when properly compensated.

DACPORT is a trademark of Analog Devices, Inc.

Bringing complete 12-bit DAC functionality and performance to your designs no longer requires having to deal with all the problems associated with external components. Instead, it simply

requires specifying our new AD767 or AD7245.

Both the AD767 and AD7245 feature an on-chip stable buried Zener reference, output amplifier and

microprocessor interface logic. And these complete functions come packed into skinny 0.3" DIPs. All this means you no longer have to deal with error budgets, product characterizations, or space constraints related to external components.

If digital interface speed is what you're after, the AD767 responds to pulse widths as short as 40ns, allowing it to be used with today's fastest processors. On the other

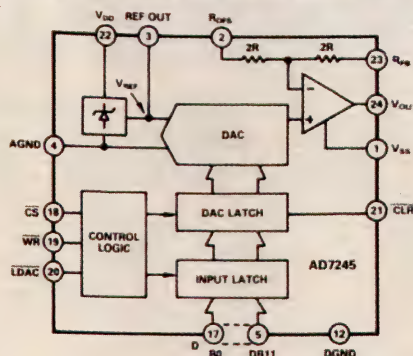


# Low Power 12-Bit D/A Converter

**AD7245**

## FEATURES

Complete 12-Bit D/A Function  
On-Chip Output Amplifier  
High Stability Buried Zener Reference  
Low Power (65mW typ)  
Single or Dual Supply Operation  
0.3", Skinny DIP Package  
8-Bit Bus Version Available: AD7248



AD7245 Functional Block Diagram

## PRODUCT DESCRIPTION

The AD7245 is a complete 12-bit, voltage-output, digital-to-analog converter with output amplifier and zener voltage reference on a monolithic CMOS chip. No external trims are required to achieve full specified performance for the part.

The part features double-buffered interface logic with a 12-bit input register and 12-bit DAC register. The data held in the DAC register determines the analog output of the converter. The input register data is latched on the rising edge of  $\overline{CS}$  and  $\overline{WR}$  and data is transferred to the DAC register under control of  $\overline{LDAC}$ . An asynchronous  $\overline{CLR}$  signal on the DAC register allows features such as power-on reset to be implemented. All logic inputs are level triggered and are TTL and CMOS (5V) level compatible, while the control logic is speed compatible with most microprocessors.

The on-chip 5V buried zener diode provides a low-noise, temperature compensated reference for the DAC. The gain setting resistors allow a number of ranges at the output: 0 to +5V, 0 to +10V when using single supply and -5V to +5V when operated with dual supplies. The output amplifier is capable of developing +10V across a 2k $\Omega$  load.

The AD7245 is fabricated in an all ion-implanted high-speed linear compatible CMOS (LC<sup>2</sup>MOS) process and is packaged in a small, 0.3" wide, 24-pin DIP.

## PRODUCT HIGHLIGHTS

- Complete 12-bit DACPORT™:**  
The AD7245 is a complete voltage output 12-bit DAC on one chip. This single-chip design of the DAC, reference and output amplifier is inherently more reliable than multi-chip designs.
- Single or Dual Supply Operation:**  
The voltage-mode configuration of the AD7245 allows operation from a single power supply rail. The part can also be operated from dual supplies to allow a bipolar output range.
- Low Power Consumption:**  
CMOS fabrication results in very low power consumption (65mW typical in single supply). This low power allows the part to be packaged in a small 0.3" wide 24-pin DIP.
- Versatile Interface Logic:**  
The high speed logic allows direct interfacing to most 16-bit microprocessors. Additionally, the double buffered interface enables simultaneous update of the AD7245 in multiple DAC systems. The part also features an asynchronous  $\overline{CLR}$  input.

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# FINALLY, THE COMPLETE STORY ON COMPLETE 12-BIT DACs.



hand, if low power dissipation is critical to your application, the LC<sup>2</sup>MOS AD7245 consumes only 65mW. There's also an 8-bit bus version of the AD7245 (the AD7248) that loads in two bytes.

To find out how the AD767 and AD7245 can tend to your complete 12-bit DAC needs, contact the Analog Devices office nearest you.

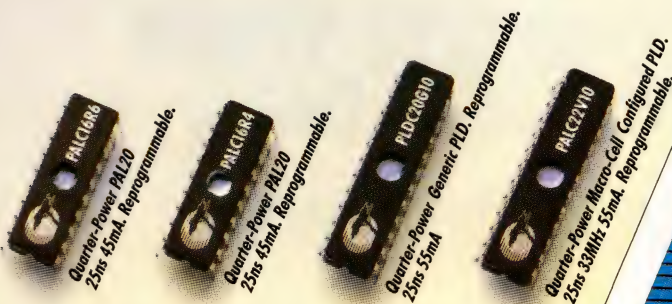
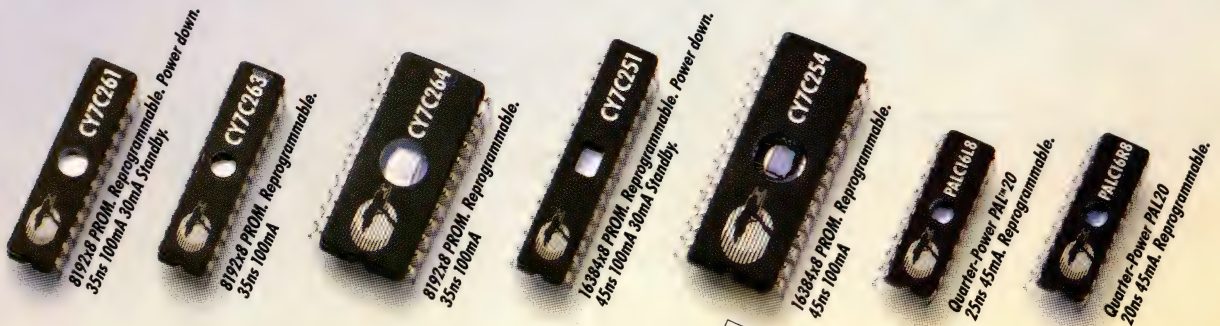
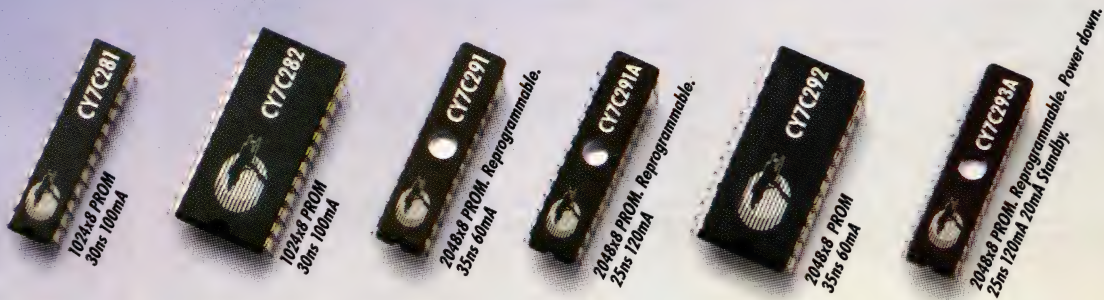
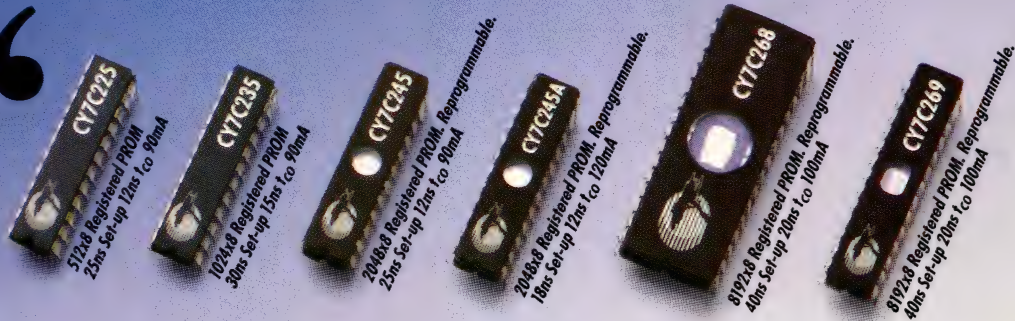
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# EDITORIAL

## Building bridges



How many EE students could we expect to graduate if university professors were to tell each freshman engineering student the day before Spring break, "Go to Radio Shack, buy components, and build a working 10-GHz FM receiver." Assume, for example, that the professors give the students no explanation and no background information, only a list of specifications. After vacation, the faculty tests the designs, but never explains why one or two work and the others don't. Instead, it's back to simple dc circuits. Probably you couldn't find a better way to sour students on electrical engineering.

A ridiculous scenario? Maybe. But equally absurd situations do happen. During the past Christmas vacation, my son—an eighth grader—had to build a bridge out of toothpicks. The assignment included strict specifications for the length, width, and height of the span as well as the requirement that the bridge be able to support a 5-lb brick. Someone with a bit of mechanical know-how might be able to build a reasonable bridge, but most 13-year-olds don't have the vaguest idea of how forces act on bridges or on toothpick structures. The brick smashed most of the models and the teacher probably said, "Too bad, yours was a poor design."

Prior to vacation there was no preparation and no explanation of how bridges work. Likewise, after the bridges were tested there was no discussion of the lessons learned from the winning designs. Because the kids were never taught about structures and forces, they could have built 50 different bridge models, none of which could withstand the brick's force. The first thing most kids learn from the bridge-building experiment is that they hate building toothpick structures.

Also, because the teacher set a lofty goal that the kids couldn't reach without proper preparation, he taught them a subtle lesson: They are stupid. By diminishing our kids' self-esteem and their interest in new ideas, we destroy a precious resource—open, inquisitive minds.

The bridge-building assignment turns into an annoyance for the kids, who rebel against it, put it off until the last day of vacation, and give it as little attention as possible. Their reaction is easy to understand. Sometimes work assignments are a lot like toothpick bridges. I'm sure I've given people jobs to do without giving them the proper tools or without being sure they have the background and the skills to do the job. It's easy to assume that coworkers and subordinates share my enthusiasm and my goals, and that they have the same overall view of a project as I do. But it's not always so. When I make my next assignments, I'll try to remember the toothpick bridges.

**Jon Titus**  
Editor

P S: If one of your youngsters brings home specs for a toothpick bridge, drop the teacher a note and suggest instead a guest lecture by an engineer. Also, you might find someone who can give the kids a demonstration of how a mechanical-CAD system evaluates simple structures.



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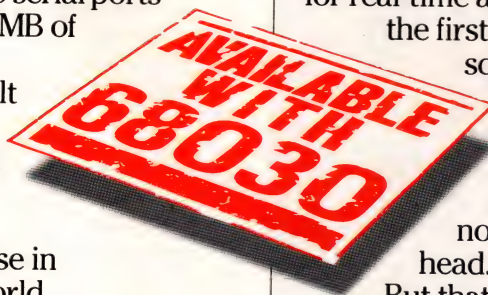
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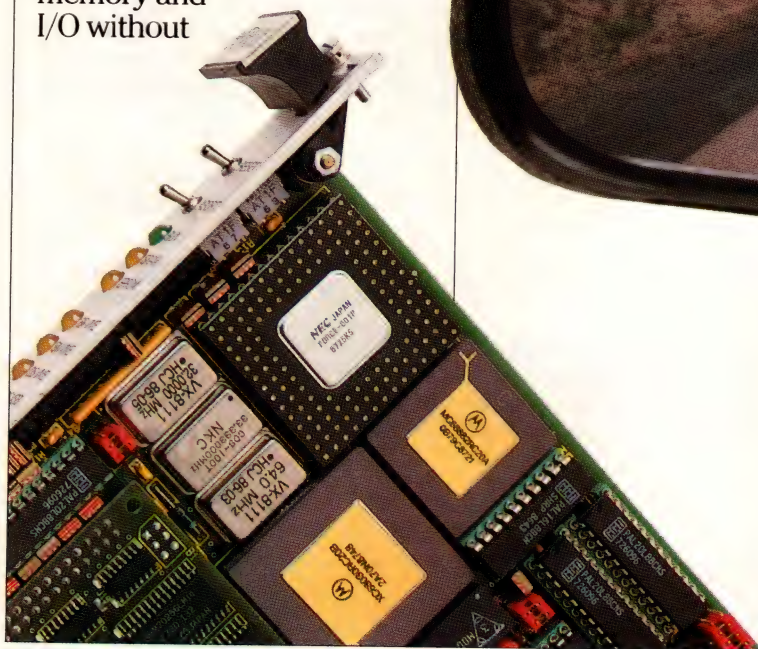
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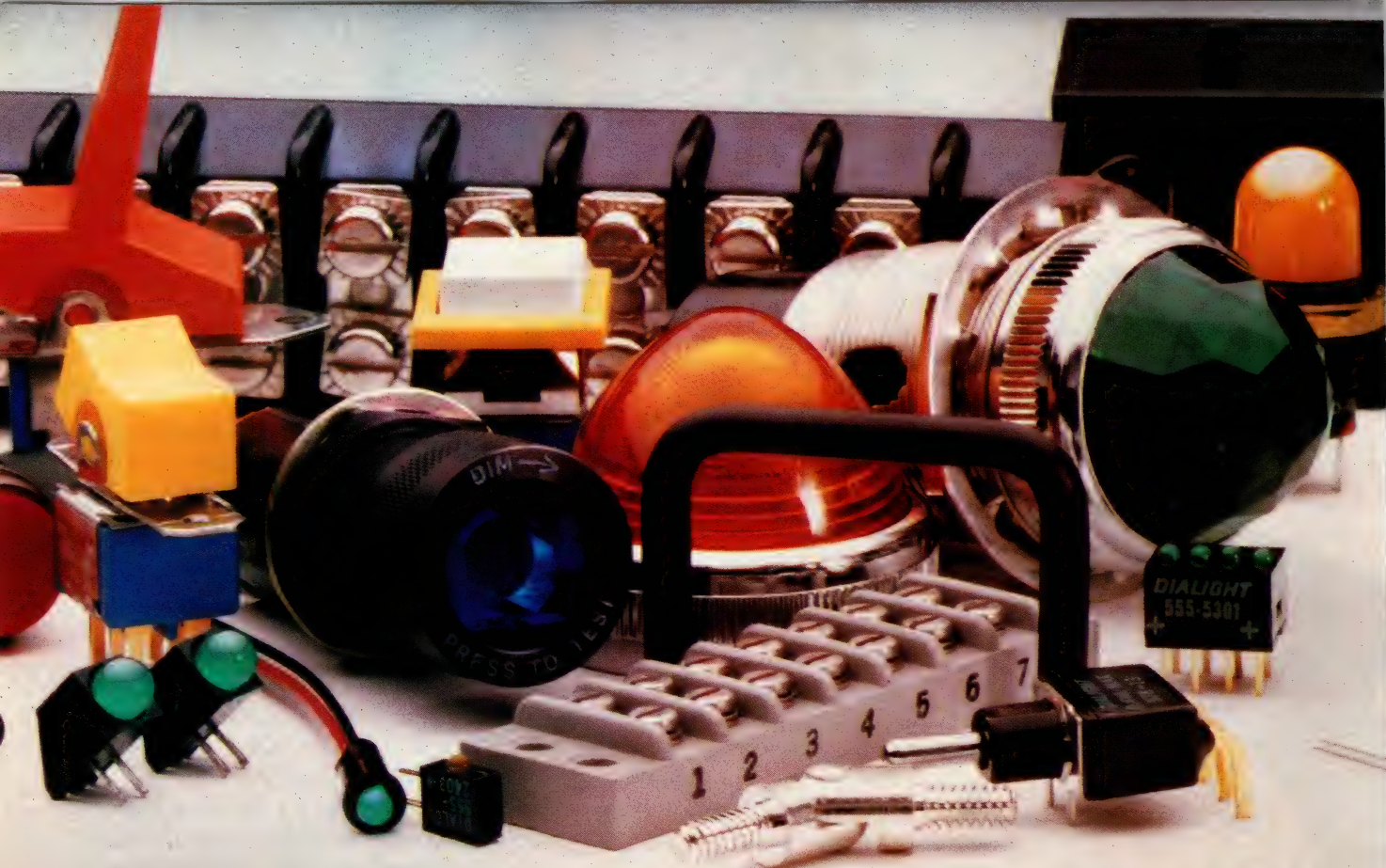
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**CIRCLE NO 157**





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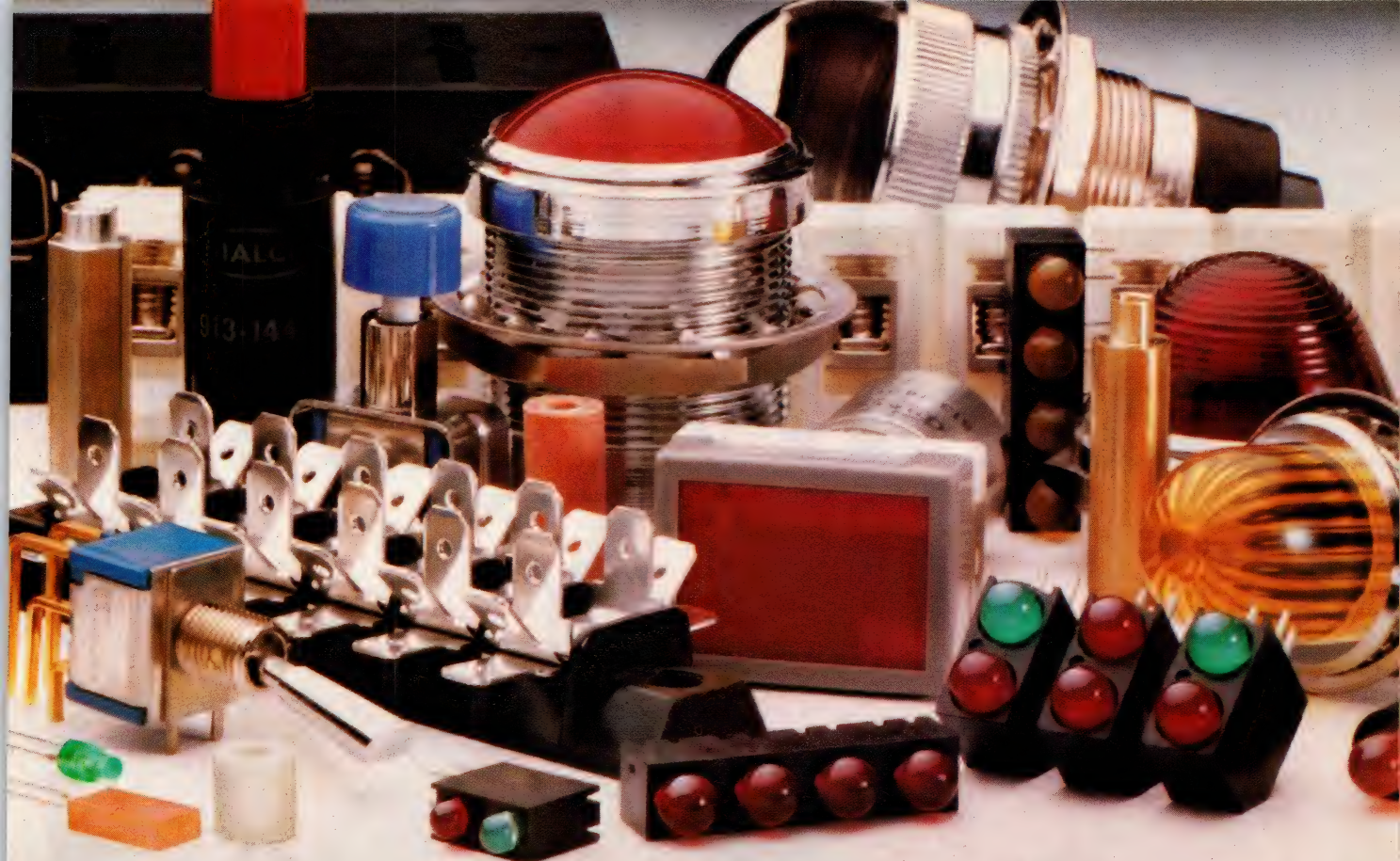
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CIRCLE NO 235



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iRMX 286	13 µsec.	self hosted	yes
VAXELN	33 µsec.	VAX/VMS	no

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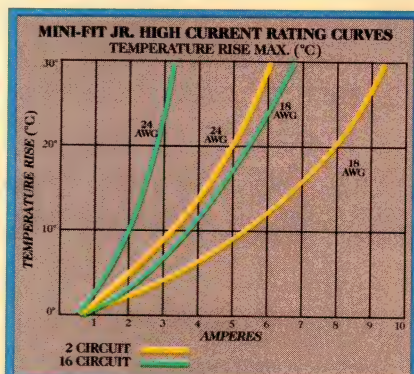
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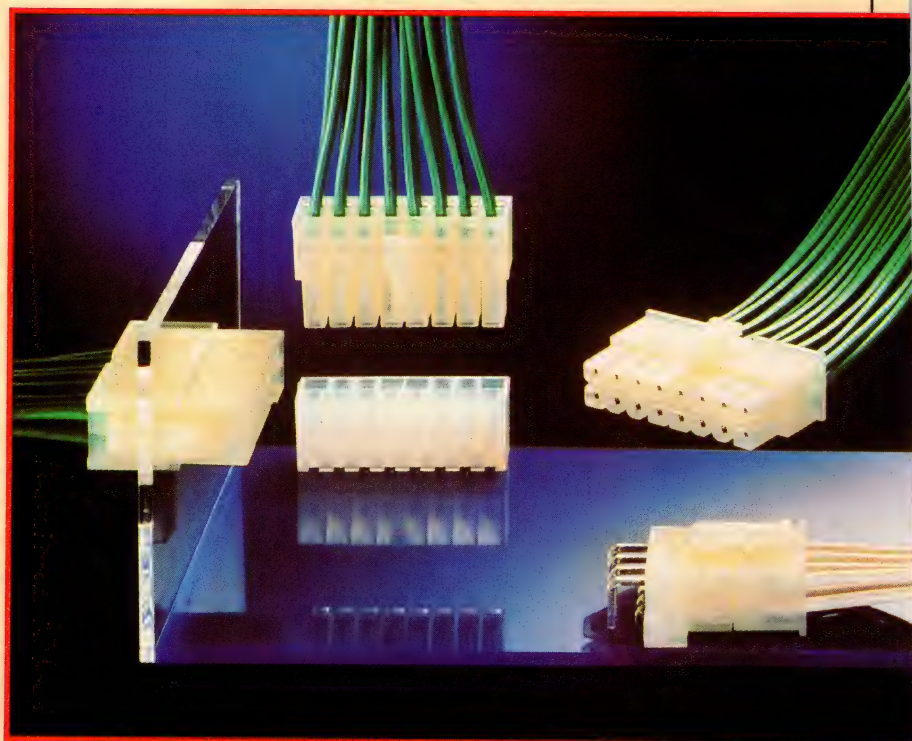
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CIRCLE NO 231

EDN February 18, 1988



# TECHNOLOGY UPDATE

## PLD-design software meets the challenge of multiple-device PLD applications

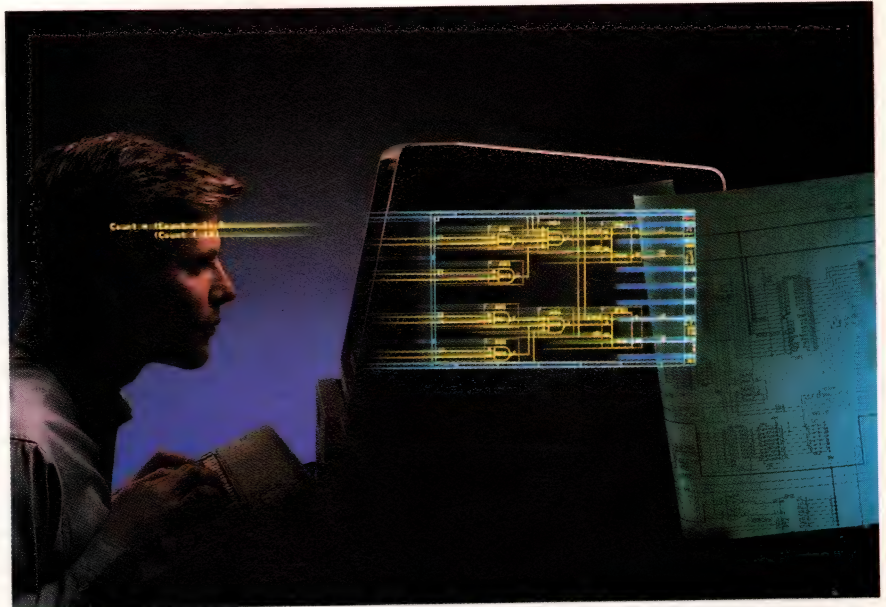
Charles H Small,  
*Associate Editor*

Until recently, engineers have tried to implement as many logic functions as they could in a single programmable-logic device (PLD) in order to use as much as possible of the device's internal circuitry. Now, however, designers are realizing logic functions that are so complex that they must be mapped over several PLDs. This trend is particularly apparent for large state machines (see box, "Extending the classical state machine"), and it's straining the capabilities of many first-generation PLD-design software packages, which were designed to handle only one device at a time.

For aid in designing with multiple PLDs, you can turn to one of a number of more recent software packages. These packages range from simple, design-entry systems to very powerful packages that can select devices for you and partition designs semiautomatically or automatically.

You may be aware that multiple PLDs aren't the only solution to the problem of realizing extensive logic functions; you could employ one of the newer, very large PLDs instead. The manufacturers of these PLDs make available custom software packages that can handle logic specifications commensurate with the capacities of their devices. However, these large PLDs are not as fast as the fastest smaller PLDs, and many companies' inventory practices don't accommodate them, so you may, in some cases, still choose to gang several 20- or 24-pin PLDs rather than adopt one of the more commodious architectures.

Multiple PLDs also make sense for designers who use PLD designs



*Providing a semiautomatic logic partitioner, Data I/O Futurenet's Futuredesigner can fit your logic designs into multiple PLDs or a gate array.*

only as an interim step, choosing to play it safe by prototyping large logic functions in PLDs before they realize the designs with gate arrays. For this kind of application, you might as well select the least expensive, most familiar parts.

### Low-cost multiple simulation

Whatever your reason for developing a multiple-PLD design, you can choose from a fairly large assortment of design aids that range from simple to very powerful and come with prices ranging from nothing to tens of thousands of dollars. The lowest-cost package for multiple-PLD design is Signetics' Amaze—it's free to qualified customers. Amaze works with the firm's PLA (programmable-logic array) and PML (programmable macro logic) devices. When you use Amaze, you must manually partition and optimize your logic design. But once you've done this work, you can submit several compiled logic specifica-

tions to Amaze's simulator simultaneously to verify your multiple-PLD design automatically.

If you wish to design with PALs instead of PLAs, you can combine MMI's Palasm 2 and Royal Electronic's Logicsim (\$79). Like Amaze, Palasm 2 has an unbeatable cost/performance ratio (it's free and it works) and it handles all of MMI's and AMD's programmable-logic devices. Palasm 2 is also like Amaze in that it requires you to partition your logic design manually. After you've derived the sets of Boolean equations for your partitioned design, you must submit your equations to Logicsim, because Palasm 2's simulator can handle only one device specification at a time.

Logicsim is a simple register-transfer logic (RTL) simulator that can handle several PLD specifications simultaneously as long as all the devices' signal names are consistent. In fact, it can work with *any* PLD-design software that produces



# TECHNOLOGY UPDATE

Boolean equations. (Most PLD-design systems offer an option that lets you print out reduced Boolean equations no matter which design-entry format you use—truth-table, schematic-capture, state-machine, state-diagram, or waveform.) You'll probably have to do some minor editing on the file of Boolean equations to put them in the right format for Logicsim.

As anyone who's ever attempted the task will testify, partitioning a logic function over several PLDs is a difficult task. The architecture of

the devices you select greatly influences the choices you can make in partitioning your design. A designer must also juggle such factors as device cost, device speed, power consumption, and alternate sourcing.

In general, there's no closed solution to the problem of selecting devices and partitioning and minimizing logic designs—especially for designs that use several asynchronous clocks or asynchronous preset and clear inputs. Given enough time and talent, a designer can massage

the equations of almost any design so that they'll fit into a particular device. Therefore, optimizing a logic design is an iterative process. Iterative processes, by their very nature, consume a lot of time, whether it's the designer's time or computer time.

If your budget can stand some greater expenditures, you can get more computer assistance: Future-designer from Data I/O Futurenet and LOG/iC from Kontron (Isdata in Europe) offer help in two different areas.

## Extending the classical state machine

The theory of classical state machines predates digital electronics. Now that you can obtain PLDs that have computer-like features such as subroutine stacks and microprogrammed architectures, you'll need to extend the classical state machine to take full advantage of these devices' features and to employ modern hierarchical-design methods.

Theoretically, the most compact and abstract description of a Mealy state machine is the mathematician's 5-tuple:

$$(I, Z, Q, \omega, \delta),$$

where vector **I** is the set of inputs to the state machine, vector **Z** is the set of states, vector **Q** is the set of outputs, and  $\omega$  and  $\delta$  are a pair of functions that relate inputs to next states and inputs to outputs, respectively.

Although the mathematical representation of a state machine serves to focus attention on the machine's elements, engineers do not find this mathematical representation particularly illuminating. They prefer, instead, to use a For-Next table (Fig Aa). In a For-Next table, each row of the table corresponds to a state of the state machine. The column headings correspond to the machine's inputs. At each intersection of a row and column are two elements: the output that the machine makes in response to the input and the next state of the machine.

But the more abstract, mathematical representation of a state machine does serve neatly as a starting point for describing state-machine extensions formally. Engineers have, for some time, employed an ad hoc, undocumented extension to the classical state machine by allowing for both regis-

tered, state-dependent outputs and asynchronous outputs (which are not accounted for in the mathematician's 5-tuple).

You can further extend the classical state machine in two ways: first, by replacing the input vector (**I**) with a more flexible menu vector (**M**), and second, by replacing the output vector (**Q**) with a more powerful action vector (**A**). The menu

STATES	INPUTS	
	$I_1$	$I_n$
$Z_1$	$Q_{t+1}$ $Z_{t+1}$	$Q_{t+1}$ $Z_{t+1}$
$Z_m$	$Q_{t+1}$ $Z_{t+1}$	$Q_{t+1}$ $Z_{t+1}$

(a)

STATES	MENU	
	$M_j$	$M_k$
$Z_1$	$A_{t+1}$ $Z_{t+1}$	$A_{t+1}$ $Z_{t+1}$
$Z_m$	$A_{t+1}$ $Z_{t+1}$	$A_{t+1}$ $Z_{t+1}$

(b)

**Fig A—**You can extend the classical Mealy state machine (a) in two ways to accommodate new PLDs having microprogrammed architectures and return stacks. As b shows, you can first substitute a set of menu choices appropriate to each state for the fixed array of inputs in a and then expand the notion of the output vector (**Q**) in a into the action vector (**A**) in b. The action vector allows the state machine to emit a sequence of outputs as well as jumps to and from submachines.



# TECHNOLOGY UPDATE

Futuredesigner is, among other things, a semiautomatic logic partitioner. It derives partitioned logic equations for a multiple-PLD design if you first select the devices and then specify which logical output will be assigned to which PLD's output pin. Depending on the options you buy, Futuredesigner can also simulate multiple-PLD designs. Futuredesigner's pricing is complex: \$7990 for logic-equation, state-machine, and truth-table design entry (the price includes an IBM PC coprocessor board); \$3990 for sche-

matic capture; and \$5500 for a Cadat simulator plus \$800 for PLD/Cadat translation software.

Kontron's LOG/iC, on the other hand, can automatically select devices and partition your design, but only if you use PLAs; if you use other devices, you must perform device selection and partitioning manually. The PLA package is \$1995; packages for other devices and simulators cost more.

Besides LOG/iC, a number of other experimental automatic device-selection, minimization, and

partitioning programs also prefer to work with the more flexible devices such as PLAs, or PLDs having programmable macrocells (the 22V10 or GAL (generic array logic) devices, for instance), rather than PALs, which have a more rigid architecture. Two recently announced software packages carry PLD-design automation a step further, however: They work with all PLDs, not just the flexible ones.

Hewlett-Packard's HP PLD design system, for example, runs on HP 9000 Series 300 workstations; it

vector (**M**) is itself a set of vectors, each vector being the set of allowable inputs for a given state. The action vector (**A**) includes the classical output vector (**Q**) but also allows the state machine to enter or exit other state machines, perform a series of actions, or emit asynchronous outputs. The expanded state machine becomes, therefore:

$$(\mathbf{M}, \mathbf{Z}, \mathbf{A}, \omega, \delta).$$

To understand why you need a menu vector for complex systems, consider, for example, electrical-drafting programs. These programs can have more than 800 commands. To represent something as complex as a state machine, you would need a For-Next table having more than 800 columns, which is clearly far too cumbersome. Therefore, when you model a large state machine having many inputs, instead of having all the inputs active all the time and ranging them across the top of the For-Next table, you recast the For-Next table so that only the allowable inputs for each state—or each line of the table—are entered right above each action/next-state entry (**Fig Ab**). Note that with this menu-like representation, your For-Next table no longer needs to be rectangular; each state has only as many entries in the table as it has allowable inputs.

Meanwhile, the output vector (**Q**) is replaced with the action vector (**A**). The action vector (**A**) allows you to break a large state machine up into a hierarchical design and to take advantage of newer PLDs' return stacks and microprogrammed architectures.

In response to an input, the expanded state machine's action vector (**A**) can emit the classical state

machine's single output (**Q**) as well as a series of outputs (assuming you have chosen a microprogrammed architecture to implement your state machine) or emit asynchronous outputs.

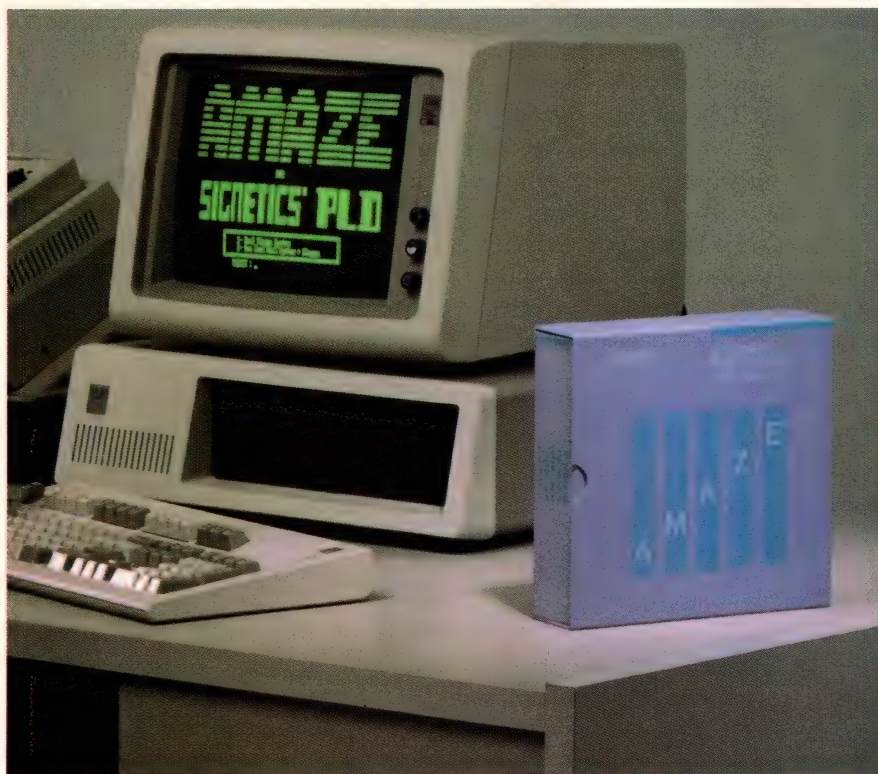
Additionally, the expanded state machine can invoke (or Enter) a lower-level state machine. Naturally, the action vector, **A**, also allows a corresponding Exit operation to leave a lower-level state machine and return control to the higher-level state machine. The term for a lower-level state machine is "submachine."

The classical state machine has no memory. It doesn't know where it came from; it knows only where it's going. To see how the concept of the submachine proves useful, consider a simple tape recorder. The recorder has buttons for stop, play, record, rewind, fast forward, and pause. The recorder's specification accepts the pause button as an allowable input when the recorder is playing, recording, rewinding, or fast forwarding. Further, the spec also states that pressing the pause button a second time should return the recorder to its previous state.

To model the operation of this tape recorder, a classical state machine would need four pause states—one each for the play, record, rewind, and fast-forward states. Modeling the recorder with an expanded state machine would involve only a single pause submachine. Pressing the pause button, in any allowable state, would cause the recorder state machine to invoke (or Enter) the pause submachine. The only allowable input to the pause submachine is the pause button. Pressing the pause button again causes the pause submachine to execute an Exit and return control to the recorder state machine.

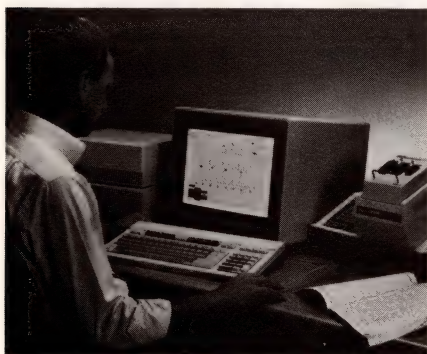


# TECHNOLOGY UPDATE



Even a low-cost PLD design system such as Amaze (from Signetics) can help you with multiple-PLD designs if its simulator can at least verify a multiple-PLD specification.

costs from \$8000 to \$14,500. (With the exception of HP PLD, all the software packages mentioned here run on IBM PCs; an IBM PC/XT or PC/AT with a hard disk is just about mandatory for these programs because of their extensive device libraries and user screens.) When you use HP PLD, you first enter your logic design without worrying about device selection. The program then automatically selects devices and partitions your design over several devices, if necessary.



The HP PLD software package automatically selects devices and fits complex PLD designs into multiple devices as necessary.

Similarly, Minc's Logic Designer (\$4500) allows you to enter your logic design in a variety of design-entry formats without first selecting a device. Logic Designer, too, searches its library of device types for the best fit for your logic specification. In contrast, older programs force you to try to compile your

design into a given device; if your design won't fit, you have no choice but to resubmit the logic equations after choosing a different part. This hit-or-miss method can prove to be time consuming and frustrating.

HP's HP PLD and Minc's Logic Designer take into consideration such device-specific factors as power consumption, pricing, and inventory restrictions when making an automatic device selection. Also, both packages have a new method of logic-design entry—waveform entry. Both packages allow you to employ a graphics editor to draw input and output waveforms from which the programs deduce logic equations. You could, for example, copy a  $\mu$ P's I/O signals from its hardware manual and combine the  $\mu$ P's signals with the waveforms from a peripheral IC's spec sheet. The programs then could automatically design a PLD that would serve as an interface between the  $\mu$ P and the peripheral IC—all without your having to write a single Boolean equation.

**EDN**

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## For more information . . .

For more information on the PLD-design software described in this article, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request service.

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**E** The first ever CECC approval for varistors has been given to the Philips 592 to 595 ranges. Forty-eight devices in the range have been approved, having maximum AC voltage ratings (RMS) between 60 and 460 V, and maximum DC voltage ratings between 85 and 615 V.

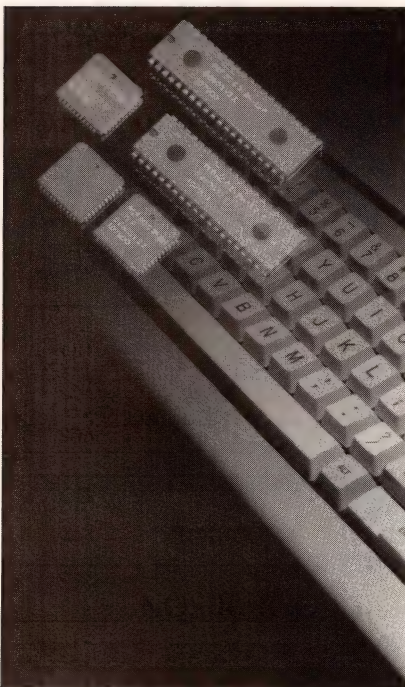
The varistors, which suppress transients to increase contact life in switching applications, withstand maximum (non-repetitive) transient currents of up to 4500 A, and are supplied taped on reel or in bulk. Two tinned, solid-copper wires connect to a zinc oxide

ceramic material with a  $\beta$  value of only 0.035 (to ensure effective transient suppression). The devices are epoxy coated to provide electrical, mechanical and climatic protection. The encapsulation is resistant to all cleaning solvents according to IEC 68-2-45. Moreover, the devices are UL-approved.

The approval demonstrates that the organization, facilities and inspection procedures for the Philips devices comply with the strict quality-assessment requirements of the CENELEC Electronic Components Committee.

Circle 73

## Latest CMOS microcontrollers in 8051 family now in full production at Philips



CMOS versions of the industry-standard 8051AH and 8031AH microcontrollers are now in full production at Philips. The new devices, type numbers 80C51BH and 80C31BH, consume one tenth the current of their NMOS counterparts – just 16 mA at 12 MHz with a 5 V supply – and have nearly double the frequency range, from 1.2 to

16 MHz. The devices suit EDP, automotive applications, and battery-powered communications equipment, especially walkie-talkies and cordless telephones.

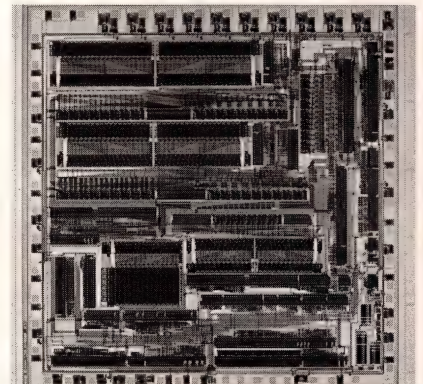
The 80C51BH is functionally identical to the 8051AH; the 80C31BH and 8031AH are ROMless versions. The 80C51BH has 4 Kbytes of ROM and 128 bytes of RAM; both ROM and RAM can be expanded up to 64 Kbytes off-chip. There are 32 I/O lines, a full duplex serial port, two 16-bit timer/counters, a five-source two-level interrupt structure, and on-chip oscillator and clock circuitry. In addition, there are software selectable idle and power-down modes.

The microcontrollers work as an arithmetic processor with facilities for both binary and BCD arithmetic and bit-handling capabilities. They have a 255 command instruction set: 44 % are one byte instructions, 41 % two byte, and 15 % three byte. With a 12 MHz crystal, 58 % of the instructions are executed in 1  $\mu$ s, and 40 % take 2  $\mu$ s (multiply and divide instructions take 4  $\mu$ s).

The devices result from an alternate source agreement with Intel. Both can be supplied in a 40-pin DIL (SOT-129) or 44-lead plastic-leaded chip carrier (SOT-187). They work between  $-40$  to  $+85$  °C (prefix PCF), 0 to 70 °C (PCB), or  $-40$  to  $+110$  °C (type number PCF80CA51BH, automotive version).

Circle 74

## Chip-set implements ISDN echo cancellation for the $U_{KO}$ specification



Philips is launching an echo canceller chip-set which is fully-compatible with the West German PTT's  $U_{KO}$  specification of the CCITT's U-interface for ISDN systems. The CMOS PCB2390 chip-set implements the key link in an integrated services digital network (ISDN) by allowing existing subscriber wiring to carry ISDN information over distances up to 8 km. Two chip-sets can be incorporated into a repeater station to span distances up to 14 km.

The PCB2390 uses DSP techniques to implement  $U_{KO}$  echo-cancellation and features an industry-standard IOM (ISDN oriented modular) interface, which connects to a range of other ISDN circuits. The chip-set is manufactured in a 2.5  $\mu$ m CMOS process.

The PCB2390 has an on-chip digital signal processor with several independent, programmed units operating concurrently, and communicating across a 14-bit control and data bus. Fitting into the network termination of an ISDN system, the circuits allow 2-wire subscriber wiring to carry 120 kbaud, full-duplex ISDN information to the exchange, where another PCB2390 accepts the data.

As specified by  $U_{KO}$  the PCB2390 converts voice and data into a form that can be transmitted down the subscriber wiring using the 4B/3T line code. This line transmission termination code maps every incoming 4 bits onto 3 ternary digits (three 3-level digits: +2, 0, and -2 V) to reduce the transmission speed.

Circle 75







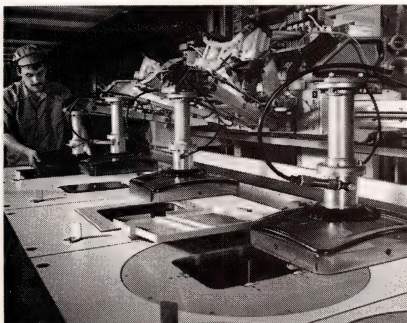
# THE COMPLETE COMPONENT COMPANY

Philips Electronic Components and Materials Division, 5600 MD Eindhoven, The Netherlands

## High-resolution colour monitor tubes now in full production

From the end of November 1987, we began full production of high-resolution colour monitor tubes at our tube factory in Durham, England. An investment of around 15 million pounds makes the factory (alongside its sister factory at Simonstone, England) the largest production centre for high-resolution colour monitor tubes in Europe, and one of the most advanced production centres in the world. Production will initially concentrate on 90°, 14 inch, high-resolution tubes, with a target of about a quarter of a million tubes per year by the end of 1988.

The market for colour monitor tubes is growing fast, from 6 million produced worldwide in 1986 to an estimated 13 million by 1990 - a growth of about 25 % per year. However, European-based monitor manufacturers currently rely on tubes imported from Japan. The expanded production at Philips will therefore reduce imports, and open up a valuable and growing export market for display systems. The new tubes will have screens displaying 800 by 600 pixels or more, and are destined for monitors used mainly for office automation being produced by the world's top computer hardware manufacturers. The Durham factory will produce these colour monitor tubes in parallel with the current 1.6 million flat-and-square television tubes being made annually on the site. The black-matrix tubes will feature a choice of glass types, screen surface treatments, and phosphors. There will be a range of deflection coil impedances, and line frequencies between 16 and 64 kHz.



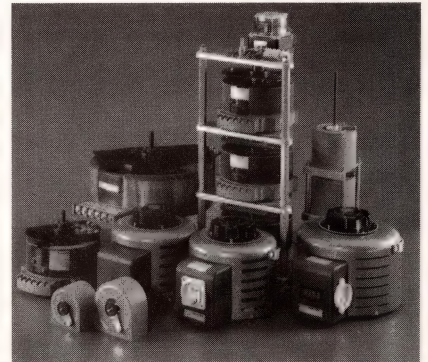
Circle 76

## Heavy-duty transformers at the price of regular types

We are extending our variable transformer range with four new types featuring input and output voltages up to 380 V. Priced at the same level as regular transformers, these heavy-duty types allow no movement of the carbon brushes over extended periods of time (24 hours) and frequent ON/OFF switching under load, as specified by VDE0552 paragraph 5g. They have exceptionally long lifetimes, and are supported by a range of accessories.

The new autotransformers suit three-phase motors and electric industrial equipment. They can be used in heavy-duty conditions without derating, with a guaranteed life of 100 000 full wipes of the brush contacts. The transformers can be run continuously at 10 % above rated current, and withstand high transient overloads.

The new transformers allow continuous control of the output voltage between 0 and 380 V (overwound versions are also available with output voltages up to almost 440 V), and pass currents of up to 4, 6, 8, and 12 A. They add to our existing range, which already includes variable transformers with input voltages from 32 to 240 V,



and rated currents up to 32 A (depending on type).

A range of spindles and other accessories are available, and the transformers may be ganged for either series or parallel connection. Ready-assembled tandem and triple transformers can be supplied, wired and tested to given specifications. A full range of motor drives are available in kit form or ready assembled, with reversible synchronous motor and gear box.

Circle 77

## High-power transistor replaces vacuum tubes in any size of FM radio transmitter

We are introducing a 250 W transistor that allows for the construction of completely transistorized FM radio transmitters of any size, thereby eliminating vacuum tubes in high-power systems and cutting out the expensive necessity of a back-up transmitter. As the BLV37 has the highest available output power to package size ratio, in lower power transmitters where transistors have already replaced tubes it can either produce more power in the available space or reduce parts count. Operating from a 28 V supply, the Class-B device features a minimum power gain of 10.5 dB and is for operation in 108 MHz transmitters in commercial networks or military and civil mobile radio.

The devices can be cascaded to build modules which are then coupled together to produce the level of output power required; fifteen BLV37s are needed for a 3 kW module. There is no theoretical limit to the number of modules that can be coupled

although considerations such as air-cooling determine the limits in practice. Modules built with the BLV37 can produce levels of power previously only obtainable with vacuum tubes, but with improved operating reliability and easier handling, installation and maintenance.

If a single module fails in a transistorized transmitter, transmission will continue on reduced power until a repair is made. Vacuum tube transmitters go off the air completely if the tube fails, therefore a back-up transmitter is needed. By guaranteeing continuous operation the BLV37 removes the need for back-up transmitters in high-power systems. The exceptional power-handling capability of the BLV37 is due to a purpose-developed chip design and a package unique to Philips. Gold metallization ensures excellent reliability.

Circle 78

# PHILIPS



# Your next destination:





# The ACL Computer Age.

## The future belongs to computers and peripherals built with RCA Advanced CMOS Logic (ACL).

The pressure is on to make your systems smaller, faster, cheaper.

Some of your competitors are doing just that by incorporating ACL into their new designs. If you want to stay on the fast track, you can't afford not to consider ACL for your new designs.

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Imagine a computer with power dissipation so low you could eliminate all cooling systems. Or design a sealed system to prevent dust problems.

And get dramatically improved reliability, thanks to the far lower heat generated. As well as far smaller system size.

You'd also be able to use it in a far wider operating temperature range ( $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ). Even in high-noise environments.

### **FAST\* speed, CMOS benefits.**

Advanced CMOS Logic gives you high speed (less than 3ns propagation delay with our AC00 NAND gate) and 24 mA output drive current.

But unlike FAST, it gives you a whole new world of design opportunity for computers, peripherals, telecommunications and other speed-intensive applications.

ACL dissipates less than 1/8 Watt while switching, compared to 1/2 Watt for a FAST IC (octal transceiver operating at 5 MHz). And quiescent power savings are even more dramatic: ACL idles at a small fraction of the power of a FAST IC.

In addition, ACL offers balanced propagation delay, superior input characteristics, improved output source current, low ground bounce and a wider operating supply voltage range.

### **Latch-up and ESD protection, too.**

Latch-up concern is virtually eliminated, because ACL uses a thin epitaxial layer which effectively shorts the parasitic PNP transistor responsible for SCR latch-up.

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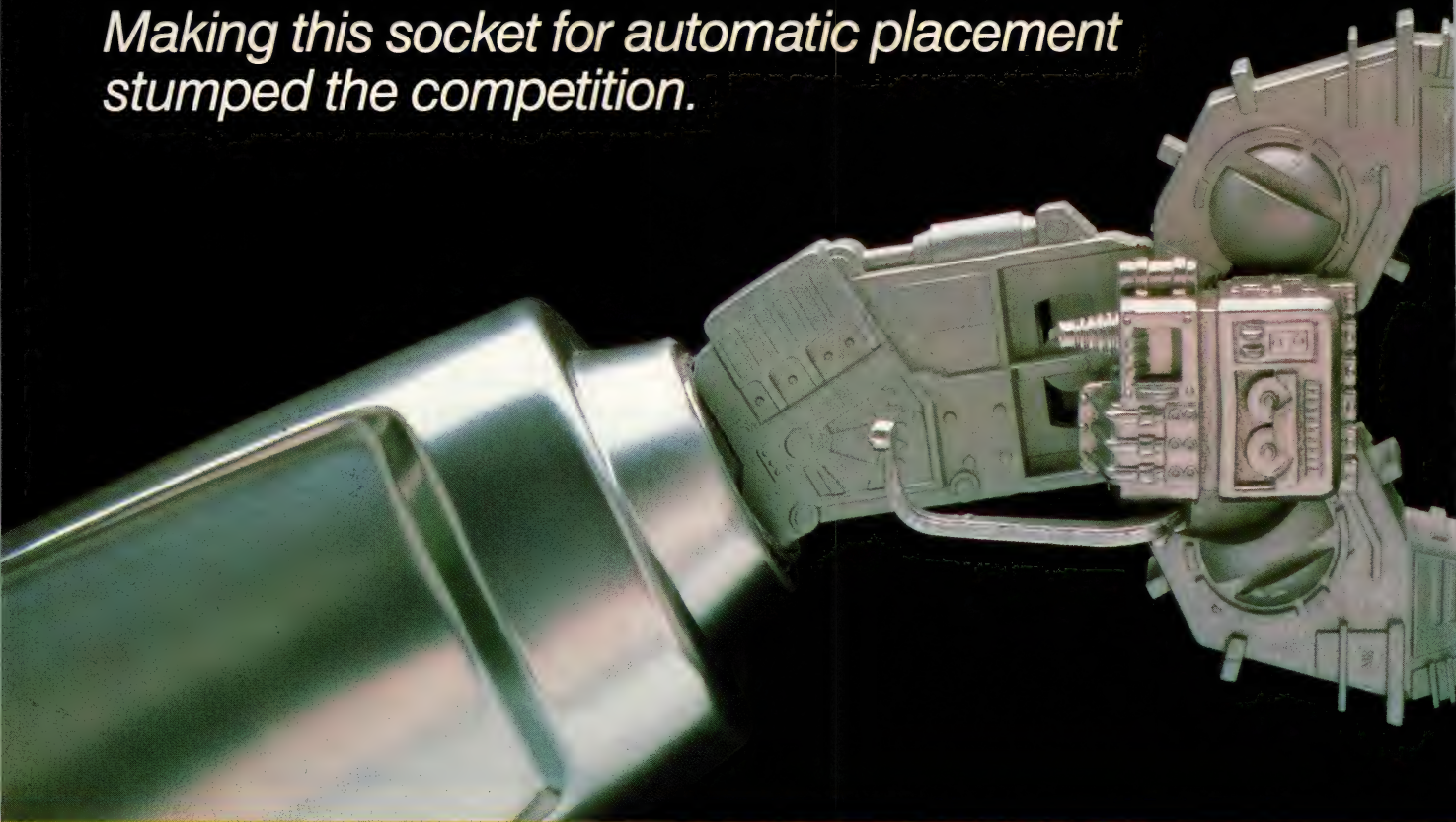
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### **GE/RCA/Intersil Semiconductors**

These three leading brands are now one leading-edge company. Together, we have the resources—and the commitment—to help you conquer new worlds.

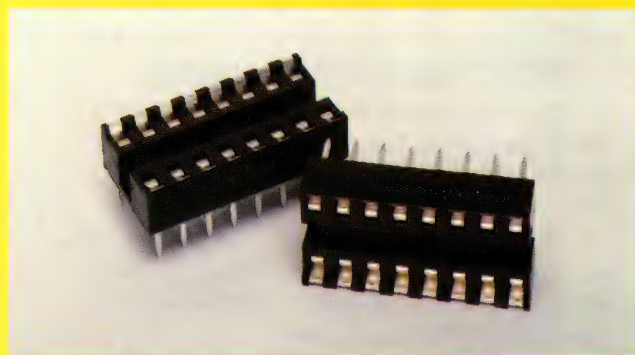


*Making this socket for automatic placement  
stumped the competition.*



This socket had been made by a major RN competitor. New, more stringent customer specs needed for automatic placement of the socket on PC boards, stumped this supplier as well as many others. The RN "P/Q TEAM", working with customer engineers, responded quickly with modifications of a standard socket that included more precise dimensions and consistent quality in higher production quantities. RN is now delivering precision, high reliability sockets to this major OEM for high speed, automatic assembly.

This is the RN "Partners in Quality Team" in action. It brings all of our engineering, production and quality control resources together with customer experts to solve socket and connector problems with speed and efficiency. Call on the RN "P/Q TEAM" for fast, certain solutions to *your* interconnect problems.



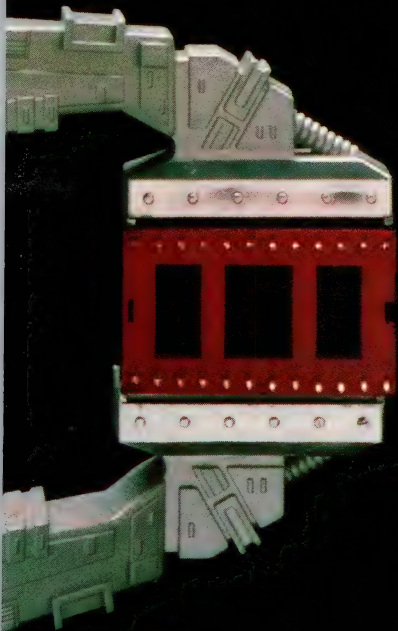
This is the socket that competitors could not make precisely enough to be assembled automatically. It is a modestly priced ICO series DIP socket. RN modified it to rigid customer specs and now produces it in large quantities of unvarying quality that meet the precise requirements of high speed assembly. Just one more example of the RN "Partners in Quality Team" solving difficult customer problems.

**CIRCLE NO 102**

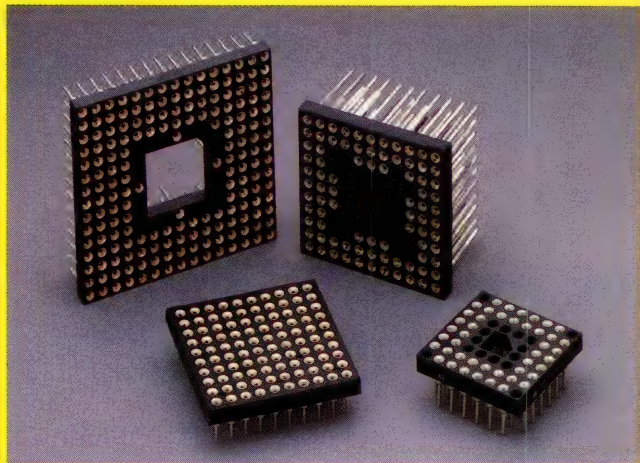
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# The RN "Partners in Quality Team" delivered precision sockets that made automatic assembly possible!



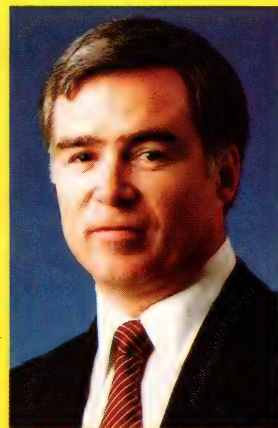
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R. A. Lindenmuth  
President/CEO



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The RN "P/Q TEAM"...your Partners in Quality



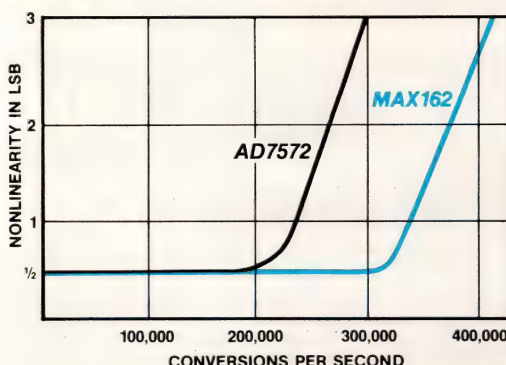
# 100,000 12-BIT A/D CONVERSIONS—FREE

**Get 3 $\mu$ s, 12-bit accuracy  
for the price of a 5 $\mu$ s AD7572 converter.**

The new 12-bit CMOS MAX162 from Maxim delivers a 40% increase in A/D conversion rate for the same price as the industry standard AD7572. That's over 100,000 more conversions per second—absolutely free.

The MAX162 packs on-chip a buried zener reference, three-state output drivers, high-speed microprocessor interface circuitry, internal or external clock options and maintains a low power drain of only 135mW. It operates from +5V and -15V or -12V supplies. And is pin for pin compatible with the AD7572.

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## Or get a low noise AD7572 from Maxim.

If your design is committed to the AD7572, consider this—Maxim's AD7572s (and MAX162s) deliver a 3X reduction in noise over the original manufacturer. And every standard part we put into a DIP is burned-in at 150°C for 24 hours—at no extra charge. This results in an incredibly low failure rate of 6.8 failures per billion hours of operation.

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So what will it be? A 3 $\mu$ s MAX162 or a 5 $\mu$ s AD7572? The price is the same. The choice is yours. And soon, that choice will include a military version screened to MIL-STD-883B Rev. C requirements.

Call your Maxim representative or distributor today for data sheets and samples. Or write Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086, (408) 737-7600. And tell them you'd like 100,000 12-bit A/D conversions—free.

\* Maxim Reliability Report RR-IC 1987.



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## Growing array of 1-chip dc/dc converters provides power for diverse applications

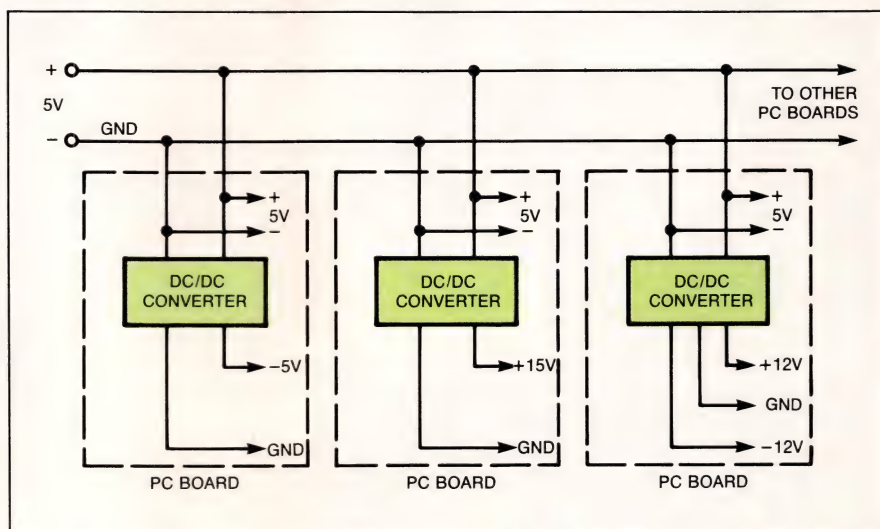
Dave Pryce, Associate Editor

The increasing variety of chip-level dc/dc converters is not only changing the way system designers structure conventional power supplies, but is also providing solutions to applications problems that were previously satisfied only by more costly and cumbersome approaches. A single, low-power monolithic IC can supply the exact amount of voltage needed for specific pc-board functions, and high-power types can simplify the design and reduce the component count of many power supplies.

The conventional way to obtain multiple dc outputs is to generate them in the main power supply and then bus them to the needed points throughout the system. An alternative approach, and one that is becoming increasingly popular, is to use the power supply's main dc output (typically 5V for computer systems) and distribute it to the various boards throughout the system for conversion to a different voltage by a small, monolithic dc/dc converter. An example of this approach is shown in Fig 1, where three board-level converters generate -5, 15, and  $\pm 12$ V from a standard 5V bus.

### Distributed power has advantages

Using a distributed approach gives you several advantages: It reduces the size and complexity of the main power supply, allows the local generation of the different voltages needed by analog circuits, and simplifies any subsequent design modifications. Not so obvious, but perhaps equally important, is that the distributed approach reduces regulation problems associated with voltage drops across lengthy wire



**Fig 1—Monolithic dc/dc converters provide easy solutions to the need for different voltages throughout a system. Shown here are three converters, operating from a 5V bus, that step up the bus voltage and/or invert its polarity.**

runs (particularly those carrying high current). Further, the local-converter approach minimizes decoupling problems.

Monolithic dc/dc converters are also useful for generating higher voltages when operated from low-voltage battery supplies such as 1.5 and 3V. Some of the new CMOS converters are particularly efficient for low- to medium-power applications. Conversely, other dc/dc converters are specifically designed to convert a high input voltage, such as the -48V from a telephone line, to a lower voltage for powering digital and/or analog systems.

Most monolithic dc/dc converters are essentially switching-regulator circuits that include the output switch, but not the usual bells and whistles associated with the typical PWM switch-mode control circuit. With the possible exception of some types that are capable of handling high voltages, dc/dc converters are designed for ease of use and low end-system cost; any required

housekeeping features are usually built into the devices.

### Converters take three forms

Depending on their input-voltage range and the output voltage (or voltages) they deliver, dc/dc converters take one of three basic forms:

- **Boost (or step-up) converter (Fig 2a)**—In this converter, the output voltage is higher than the input voltage. The higher output voltage is a result of the voltage developed across the inductor, which stores energy as a function of the switching frequency and the duty cycle.
- **Buck (or step-down) converter (Fig 2b)**—This converter's voltage is lower than its input voltage. The converter chops the input voltage into a pulse train. The switching duty cycle determines the output voltage, but the inductor voltage does not add to the input



## A collection of various electrical switches and components, including toggle switches, push buttons, and rotary switches, displayed on a white surface. The components are arranged in a circular pattern around a central white, angular, sculptural object. The switches include a large black toggle switch with a white handle, a smaller black toggle switch with a red handle, a black push button with a green indicator, a black push button with a red indicator, a black rotary switch with a white handle, and a black rotary switch with a green handle. The background is a dark, textured surface.

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# TECHNOLOGY UPDATE

voltage as is the case with the boost converter.

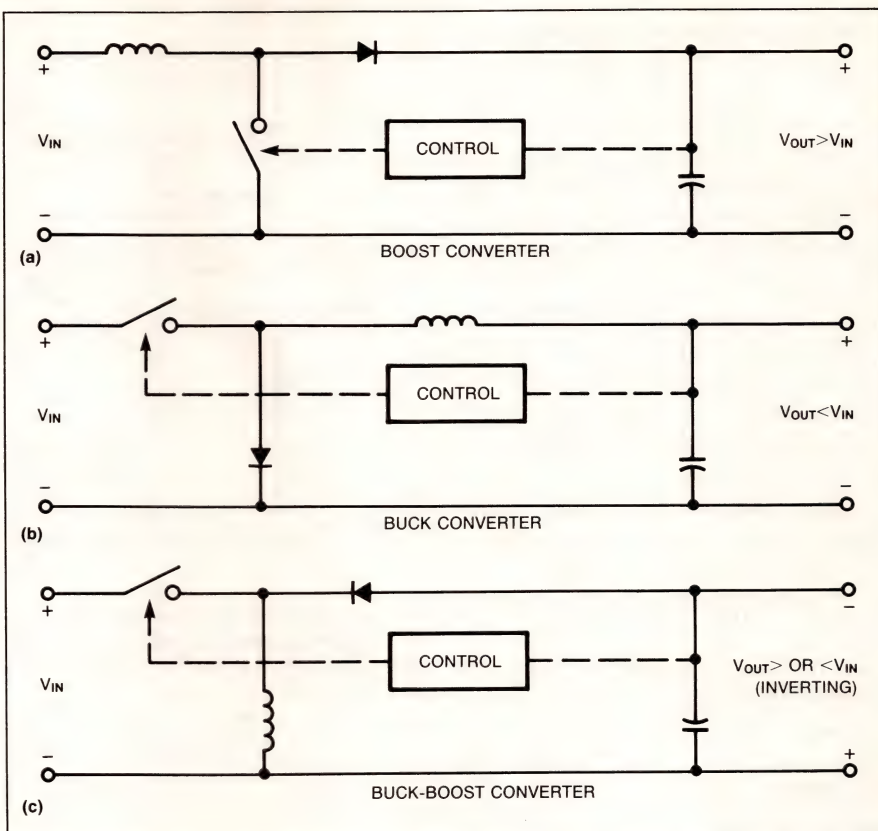
- Buck-boost (or step-up/step-down) converter (**Fig 2c**)—This converter's output voltage can be either higher or lower than its input voltage, depending on the duty cycle of the switching. This type of converter inverts the polarity of the output with respect to the input.

Typical examples of the currently available crop of low-power CMOS converters are two devices from Maxim Integrated Products. The MAX632 and MAX636 (**Fig 3**) are complementary in nature; both operate from an input voltage of 5V, but the MAX632 provides a positive 12V output, and the MAX636 provides a negative 12V output. Each device comes in an 8-pin plastic DIP.

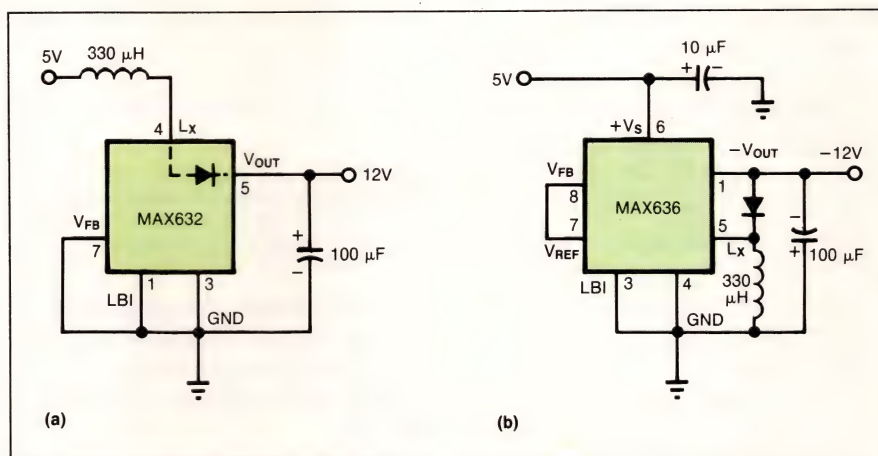
These converter types are ideal for powering low-power analog circuits from a 5V digital bus. They're relatively inexpensive and require very few external components. The MAX632 even includes a built-in diode, although you can use an external diode for greater efficiency, if you wish. For best results, the external diode should be a switching type such as the 1N4148 or the 1N5817 (Schottky).

Standard rectifier diodes designed to work at 60-Hz line frequency don't function very well at switching frequencies in the 40-kHz range. When used as shown in **Fig 3**, the MAX632 provides an output of 12V at 25 mA (with about 85% efficiency) and the MAX636 provides an output of -12V at 15 mA (with about 75% efficiency) (**Ref 1**).

Model LM3578 from National Semiconductor is a versatile bipolar device that you can use as a step-up (boost) converter, a step-down (buck) converter, or (with the aid of an external transistor) a polarity-inverting, step-up/step-down (buck-boost) converter. **Fig 4** shows the internal functions of the device, which has some unusual features. The input comparator stage has



**Fig 2—A dc/dc converter can take one of three basic forms.** The boost converter (a) steps up the input voltage, the buck converter (b) steps down the input voltage, and the buck-boost converter (c) can either step up or step down the input voltage while inverting its polarity.



**Fig 3—Low-power CMOS converters** are ideal for providing the unique voltage requirements of analog circuits from a 5V digital bus. Here, two different models provide 12V (a) and -12V (b) for different applications.

both inverting and noninverting inputs that simplify circuit design, and you can reference the external current-limit circuitry to either ground or the  $V_S$  pin.

Depending on the chosen configuration, you can take the output from either the collector or the emitter of the output transistor. The LM3578

operates from any dc voltage in the 2 to 40V range and can supply output currents as high as 750 mA. The oscillator frequency is adjustable to 100 kHz, and duty cycles to 90% are possible. As is the case with many low- to medium-power dc/dc converters, the LM3578 comes in an 8-pin DIP.



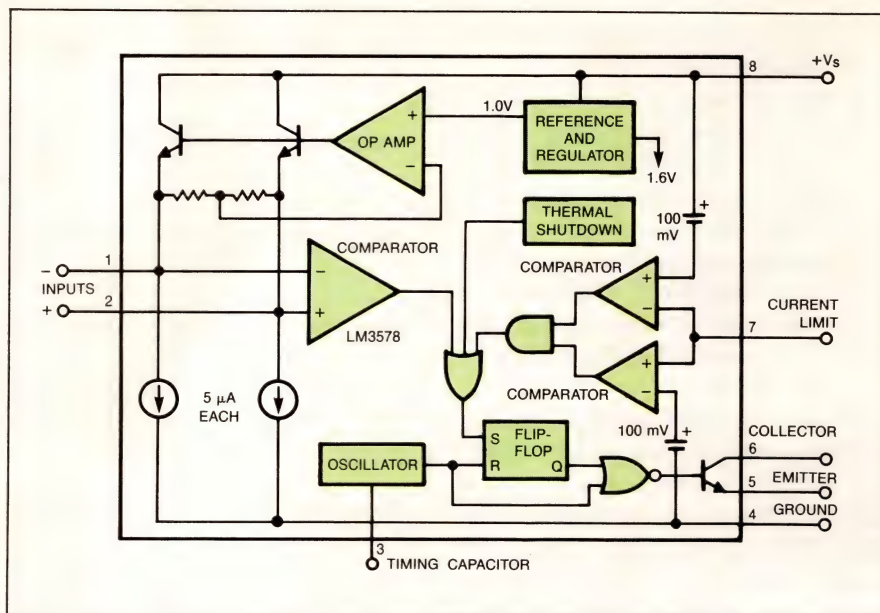
# TECHNOLOGY UPDATE

Although they also perform voltage conversion, the LTC1044 and LTC1054 from Linear Technology Corp operate differently than do the converters previously discussed. The LTC1044 and LTC1054 provide voltage conversion by means of a switched-capacitor method. The LTC1044 (Fig 5) is pin compatible with the popular 7660 type but has some improved performance specifications, including the capability of operating over a 1.5 to 9V input-voltage range without external protection diodes.

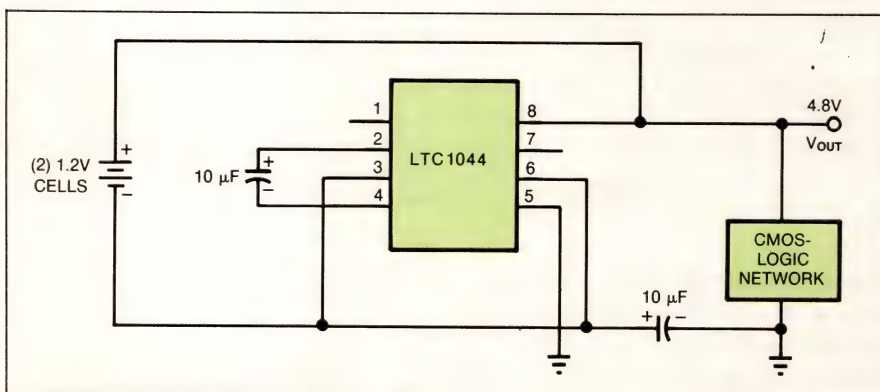
The LTC1044 is a CMOS device that's ideal for converting a low voltage from a battery (such as two 1.2V mercury cells) to a 4.8V supply for powering CMOS logic. The LTC1054 is a bipolar type that's pin compatible with the LTC1044/7660 types, but can utilize higher currents (it draws 100 mA; the LTC1044 draws 20 mA). The LTC1044 and LTC1054 are versatile, low-power devices. You can use them to double, halve, or invert an input voltage. Both converters are packaged in 8-pin DIPs.

Resembling more a controller than a complete dc/dc converter, the RC4292 from Raytheon converts a negative input voltage to a positive and/or a negative output voltage. The RC4292 can accept a wide range of input voltages, from a minimum of -20V to a maximum of -120V, and can provide an output voltage from -24 to +24V with a typical efficiency of 70%. The output-drive capability of this bipolar device is 350 mA. Although you can use the IC on a stand-alone basis, most applications of the RC4292 incorporate an external power transistor and a transformer.

One such application is shown in Fig 6, in which the RC4292 converts the off-hook telephone-line voltage of -48V to a 5V output suitable for powering digital circuits. The external power MOSFET drives the transformer, which steps down the supply voltage. By rearranging the output rectifier, you can provide a



**Fig 4—This monolithic converter can step up, step down, or invert the input voltage. To invert the input voltage, the device (the LM3578 from National Semiconductor) requires an external transistor.**



**Fig 5—A good choice for powering CMOS logic, the LTC1044 from Linear Technology Corp uses two 1.2V mercury cells as the input-voltage source in this application. The converter provides an output of 4.8V at low current.**

negative output; by using a transformer having multiple windings (along with two rectifiers) you can provide both positive and negative outputs.

Similar to the Raytheon RC4292 in their ability to handle high input voltages are the Si9100 and Si9102 from Siliconix. These D/CMOS types, however, include the power switch on chip and offer a somewhat more versatile architecture. These more-complex devices therefore require a 14-pin DIP rather than the 8-pin DIP of the RC4292. The Si9100 has an input-voltage range of 10 to 70V and can supply 350 mA of output current. The Si9102 has an

input-voltage range of 10 to 120V and an output-current rating of 250 mA.

Although you can use them without a transformer for nonisolated applications, the Si9100/9102 find principal use in transformer-coupled flyback- and forward-converter applications. Such applications include ISDN and PBX equipment, modems, and distributed-power systems. Thanks to their high input-voltage ratings, you can operate these devices directly from the -48V telephone line. The 120V-rated Si9102 can operate from -96V double-battery telecommunications power supplies.



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CIRCLE NO 123

77



# TECHNOLOGY UPDATE

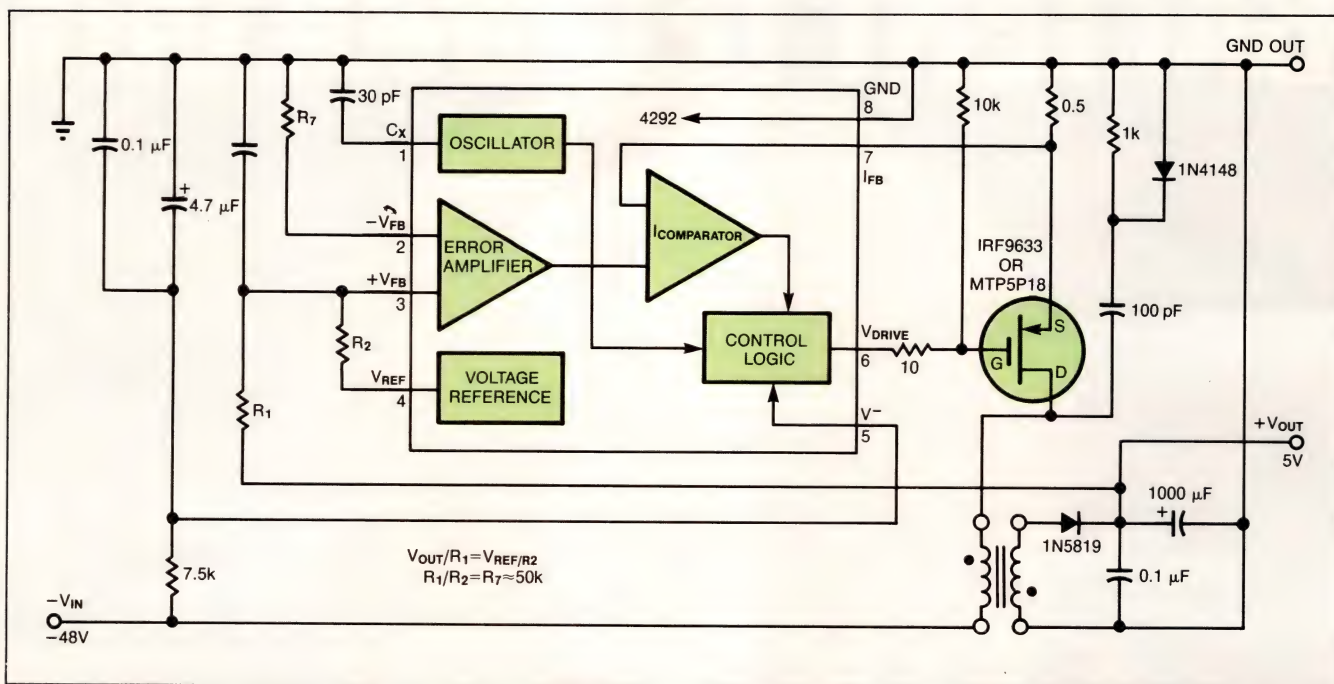
Climbing to the high-power rung of the dc/dc-converter ladder, you can find types from Linear Technology Corp, Lambda, and SGS that are capable of providing output currents from 1.5 to 10A.

The LT1070 from Linear Technol-

ogy Corp has an input-voltage range of 3 to 60V and can deliver 5A output current; it's available in either a 5-pin TO-3 package or a 5-pin TO-220 package. The LT1070 is a current-mode control chip. This operating mode offers the advan-

tages of pulse-by-pulse current limiting and the reduction of the 90° phase shift in the inductor (**Ref 2**).

Several high-power dc/dc converters are available from Lambda Semiconductors. The LSH6300 Series includes devices that have cur-



**Fig 6**—Useful in telecomm applications, this circuit uses the RC4292 from Raytheon to convert the off-hook telephone-line voltage of -48V to a 5V output suitable for powering digital circuits.

## REPRESENTATIVE MONOLITHIC DC/DC CONVERTERS

VENDOR	PART NUMBER	INPUT VOLTAGE (V)	OUTPUT VOLTAGE (V)	OUTPUT CURRENT (A)	OPERATING FREQUENCY (kHz)	PROCESS TECHNOLOGY	PACKAGE	PRICE
LAMBDA	LSH6325P	12 TO 35	5 TO 27	2	70	BIPOLAR	5-PIN TO-200	\$11.22 (100)
LINEAR TECHNOLOGY CORP	LT1070	3 TO 60	CIRCUIT-DEPENDENT	5	40	BIPOLAR	5-PIN TO-3	\$9.60 (100)
	LTC1044	1.5 TO 9	$V_{OUT} = 2V_{IN}$	0.020	10	CMOS	5-PIN TO-220	\$7.45 (100)
	LT1054	3.5 TO 15	$V_{OUT} = V_{IN}/2$ $V_{OUT} = -V_{IN}$	0.100	35	BIPOLAR	8-PIN DIP	\$1.95 (100)
MAXIM INTEGRATED PRODUCTS	MAX630	2 TO 16.5	$V_{OUT} > V_{IN}$	0.375	75	CMOS	8-PIN DIP	\$3.50 (100)
	MAX638	3 TO 16.5	$V_{OUT} < V_{IN}$	0.375	65	CMOS	8-PIN DIP	\$3.32 (100)
	MAX632	2 TO 12.6	12	0.325	50	CMOS	8-PIN DIP	\$3.50 (100)
	MAX636	2 TO 16.5	-12	0.375	50	CMOS	8-PIN DIP	\$3.32 (100)
	MAX680	2 TO 6	4 TO 12 -4 TO -12	0.010	8	CMOS	8-PIN DIP	\$2.16 (100)
NATIONAL	LM3578	2 TO 40	$V_{OUT} > V_{IN}$ $V_{OUT} < V_{IN}$	0.750	100	BIPOLAR	8-PIN DIP	\$1.40 (1000)
RAYTHEON	RC4292	-20 TO -120	-24 TO 24	0.350	100	BIPOLAR	8-PIN DIP	\$2.65 (1000)
SGS	L4962	9 TO 46	5 TO 40	1.5	150	BIPOLAR	16-PIN POWER DIP	\$1.50 (10,000)
	L4970	15 TO 50	5 TO 40	10	500	BCD	15-PIN MULTIWATT	\$4.50 (10,000)
SILICONIX	Si9100	10 TO 70	$V_{OUT} < V_{IN}$	0.350	120	D/CMOS	14-PIN DIP	\$5.43 (100)
	Si9102	10 TO 120	$V_{OUT} < V_{IN}$	0.250	120	D/CMOS	14-PIN DIP	\$5.97 (100)





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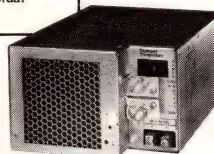
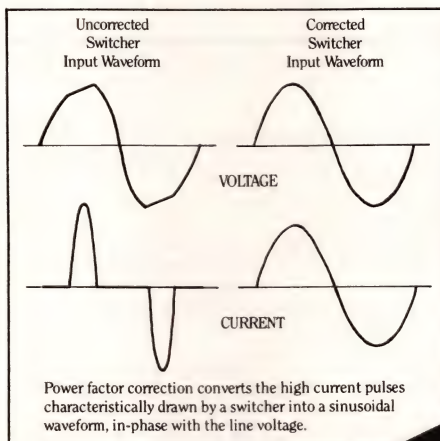
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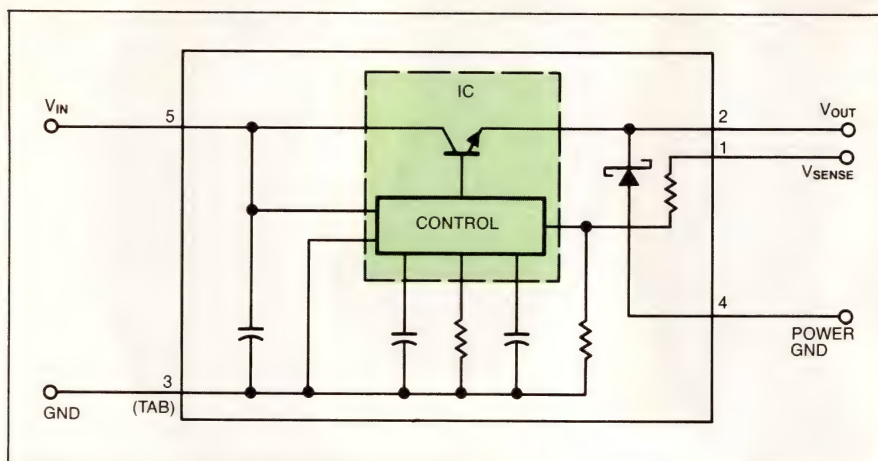
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# TECHNOLOGY UPDATE



**Fig 7—This hybrid 2A dc/dc converter** from Lambda integrates a monolithic control/power chip with a Schottky diode, thick-film resistors, and chip capacitors on a single substrate.

rent ratings of 2, 3, and 5A. The LSH6300 types (Fig 7) are actually miniature hybrids packaged in a TO-220 case. In each of these devices, however, the monolithic section is the heart of the converter: It contains the regulator, error amplifier, comparator, oscillator, current-limit circuitry, logic circuits, and output switching transistor.

The monolithic chip—along with a Schottky diode, thick-film resistors, and chip capacitors—is mounted on a ceramic substrate. You need to add only an external inductor and one or two capacitors to form a complete step-down dc/dc converter. The LSH6300 converters are normally set for a 5V output, but

you can program each device for higher voltages by adding a resistor between the output pin and the sense pin.

Finally, two more excellent examples of high-power dc/dc converters are the L4962 and L4970 from SGS Semiconductor. The L4962 is a bipolar device that has an input-voltage range of 9 to 46V, an output-current rating of 1.5A, and a maximum operating frequency of 150 kHz. The L4962 is housed in a 16-pin power DIP. For high-power applications, the L4970 has an input-voltage range of 15 to 50V and an output-current rating of 10A. The L4970 is fabricated in a bipolar-CMOS-DMOS (BCD) process that

allows you to operate the device at frequencies as high as 500 kHz. Because of its high-current and high-power capabilities, the L4970 comes in a rugged 15-pin package (called "Multiwatt") that has a long metal tab that aids in dissipating heat.

Although your present designs may not need the assistance of a dc/dc converter, chances are that future ones will. The use of a single system-supply voltage (usually 5V) is increasing in popularity, and it's a simple matter to provide the required on-card voltages for analog circuits by using a small, monolithic dc/dc converter that can step up or invert the bused voltage.

Monolithic converters can also simplify the design of your system power supply by combining several functions on a single chip. Although manufacturers of ICs are responding to the need for single-supply components by introducing new op amps, comparators, A/D converters, and other analog circuits, the use of the traditional dual-supply analog circuit will probably dominate most applications for an extended period. Whatever your application's needs, it's likely that one of the available dc/dc converters will satisfy them.

**EDN**

## References

1. Sherman, Len, "DC/DC converters adapt to the needs of low-power circuits," *EDN*, January 7, 1988, pg 145.
2. Williams, Jim, "Regulator IC speeds design of switching power supplies," *EDN*, November 12, 1987, pg 193.

## For more information . . .

For more information on the dc/dc converters discussed in this article, contact the following manufacturers directly or circle the appropriate numbers on the Information Retrieval Service card.

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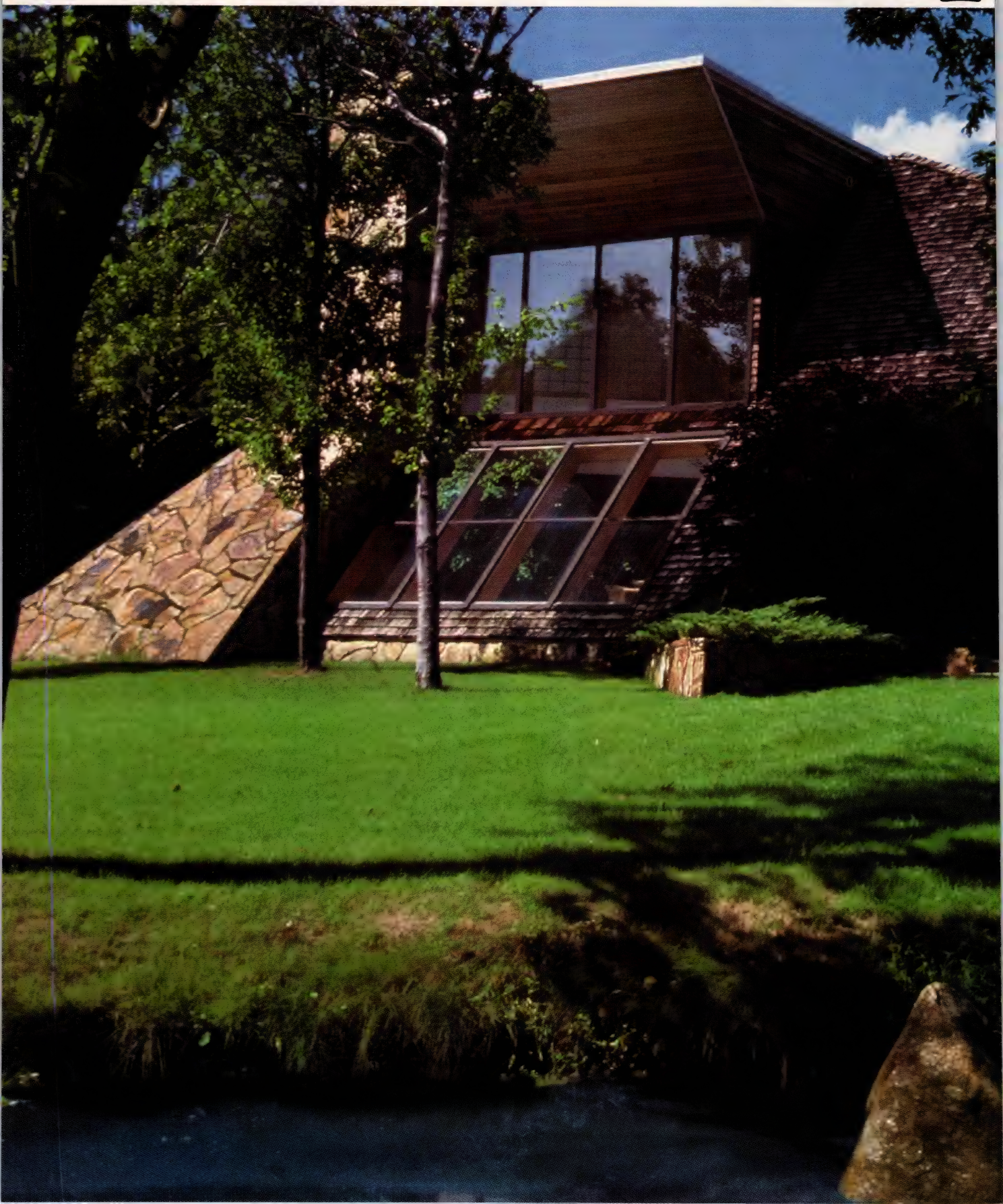


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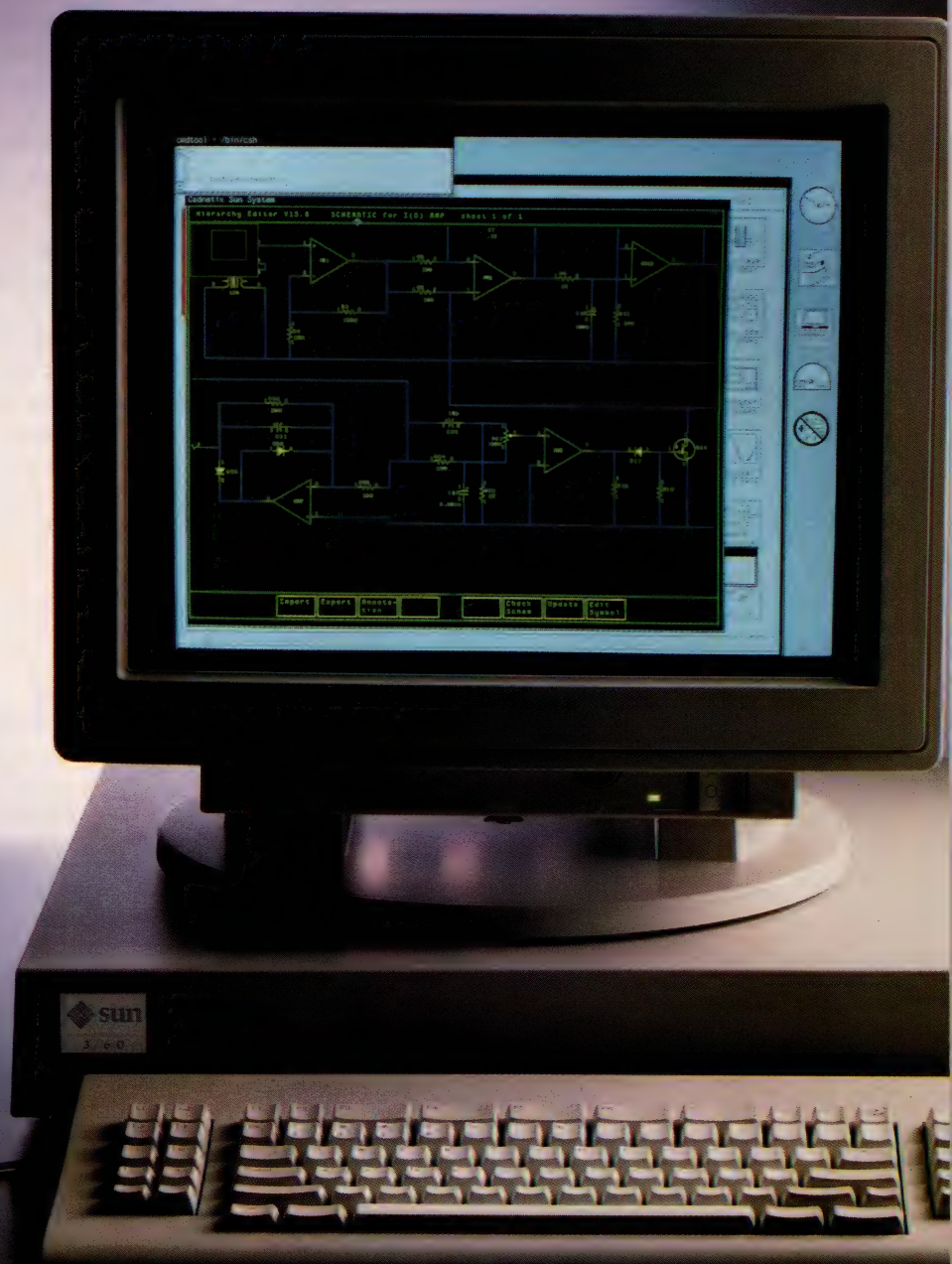


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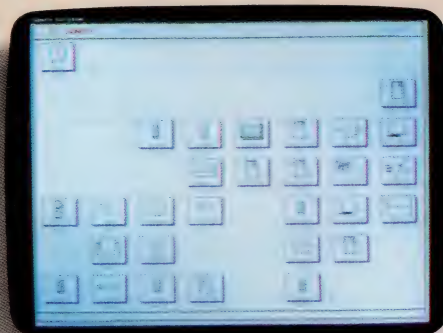


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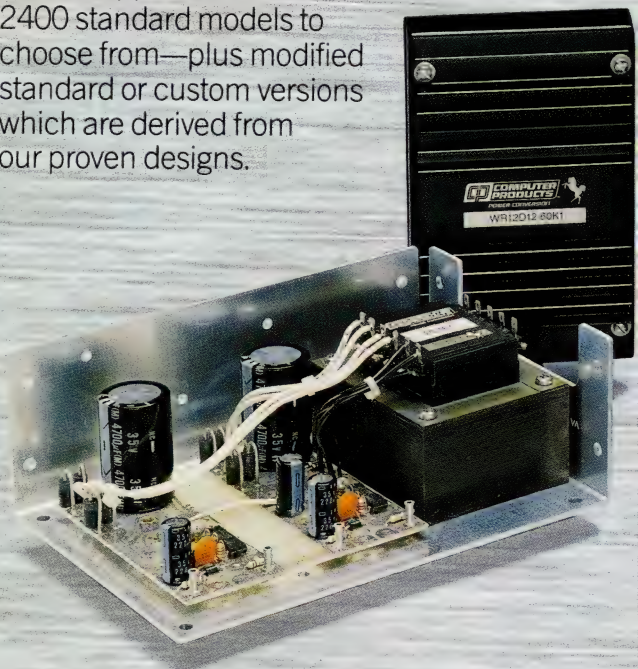
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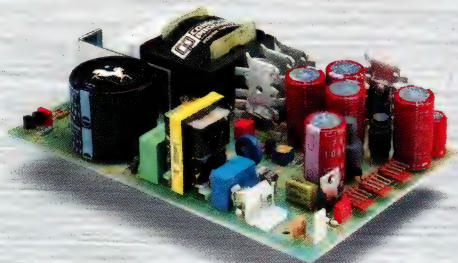
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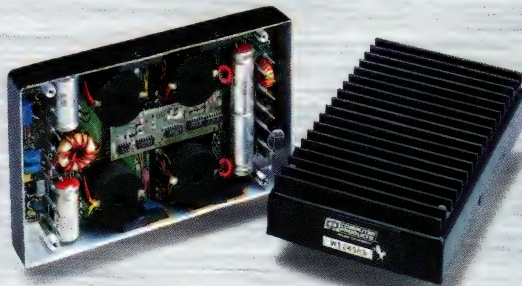


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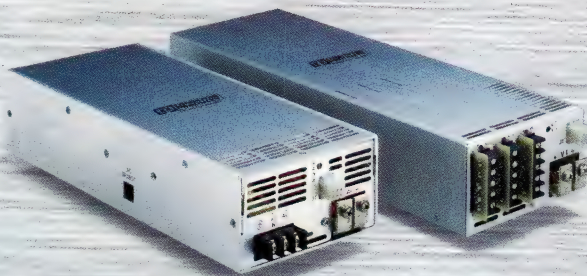
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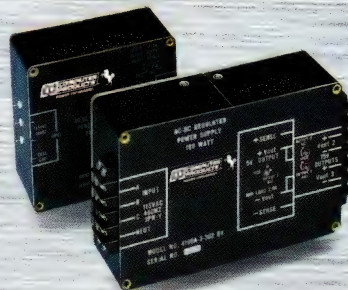


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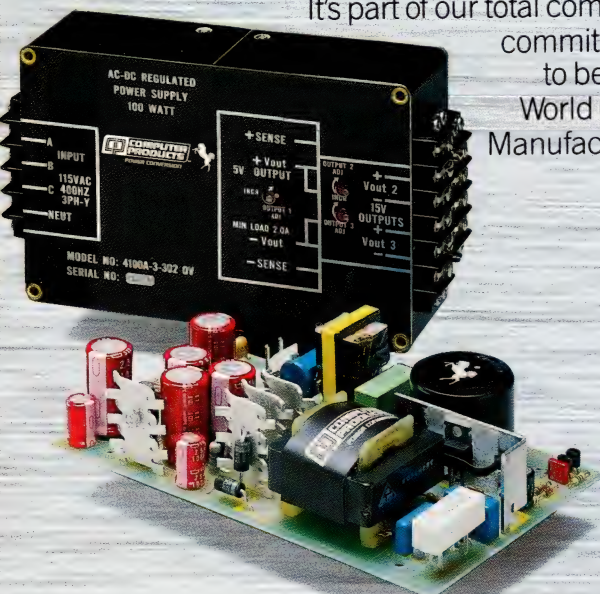
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POWER CONVERSION





## New software tools run IBM PC software on a variety of 32-bit $\mu$ Ps

Robert H Cushman,  
*Special Features Editor*

Most industry observers agree that the vast wealth of MS-DOS-based software is what gives the 8086  $\mu$ P family such a decided advantage over other  $\mu$ Ps. That situation is changing, though: Several software packages now let your MS-DOS-based software run on non-8086-family  $\mu$ Ps. (The 8086 family includes the 8088, 80186, 80188, 80286, and 80386 chips.)

By today's reckoning, the value of readily available MS-DOS software is approaching \$10 billion. Most of it has been developed as a direct response by third-party software developers to the availability of the 8088-based IBM PC. Thus, most of that software exists as 8088 or 8086 assembly-language instructions, which makes it unusable with other  $\mu$ Ps (see **box**, "The IBM PC aberration").

Such a lopsided software situation couldn't go unnoticed, so it's no surprise that enterprising software developers now offer the means for running your MS-DOS-based software on other popular—or promising— $\mu$ P chips. Three new software packages don't involve the older and more obvious technique of inserting an 8086-based CPU board into a computer. The non-8086 target  $\mu$ P of first choice is probably Motorola's 68020, but there is growing interest in other  $\mu$ Ps, particularly those that promise extremely high-speed operation.

Two such software solutions are Phoenix Technologies' Software Co-Processor and Insignia Solutions' SoftPC. These packages simulate the IBM PC's hardware and software configuration within a non-



**Multiple MS-DOS-based programs can run on workstations.** The SoftPC program Insignia Solutions supplies pictorial representations of the IBM PC's monitor that indicate which programs are running. The screen shows Digital Research's GEM (including the calculator), as well as Lotus 1-2-3, Wordstar 2000, Sidekick, and Flight Simulator. Unix uses the window in the lower right corner of the screen to note its operations.

8086-based system. They also translate the 8086 instructions so that the MS-DOS-based program will operate properly. (Although the programs provide simulation as well as instruction-interpretation or -translation functions, you can call them translation programs for simplicity's sake.)

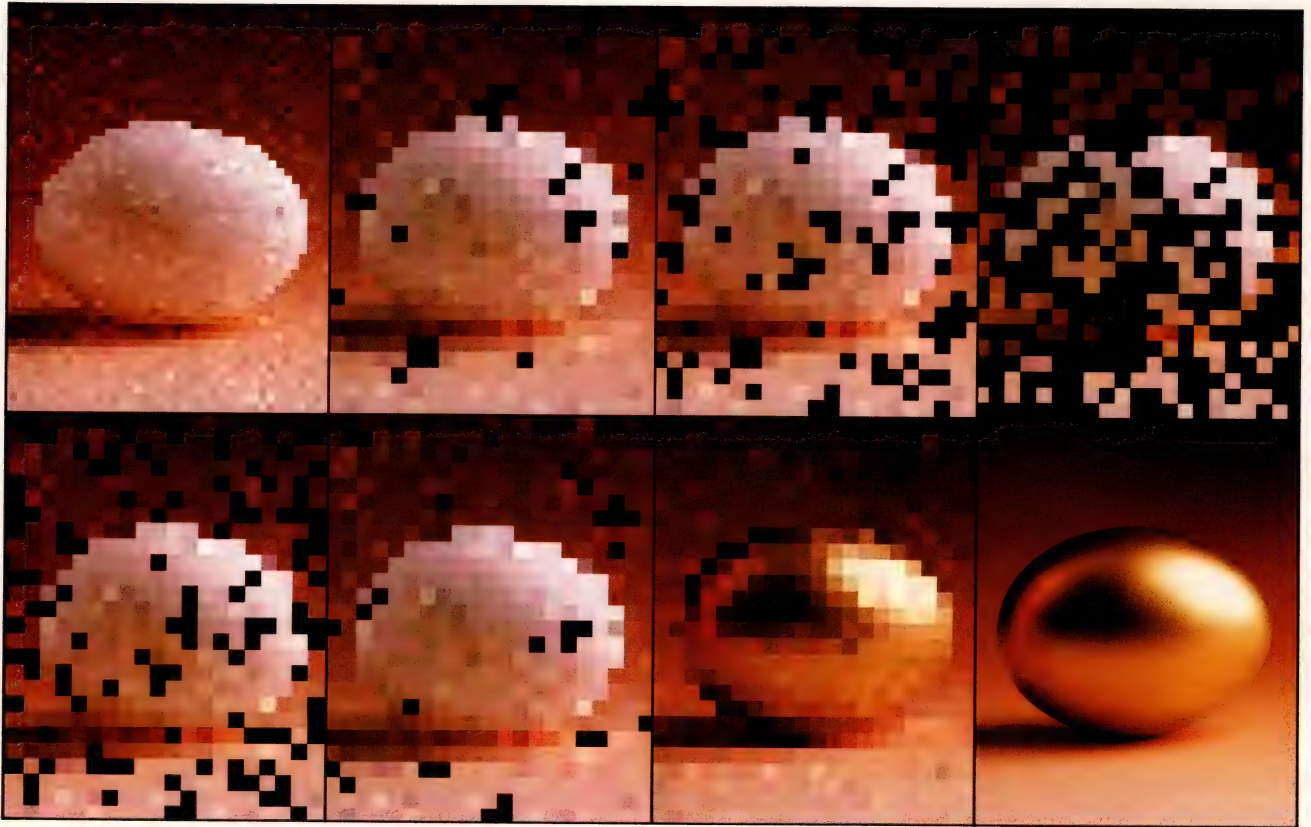
First, you must load the translation software into your target computer, then you can load and run an MS-DOS-based application program. The Phoenix and Insignia programs interpret each 8086 instruction as the target computer fetches it from memory; the software traps and decodes each instruction and remaps I/O and memory operations to suit the target system's configuration. The transla-

tion software simulates the IBM PC's resources, which include the MS-DOS code, the basic input-output system (BIOS) code, pertinent I/O devices, and possibly a graphics display. The software cannot simply interpret the MS-DOS-based program instruction by instruction, because the interpretation process would be too slow. Therefore sophisticated programming techniques—some possibly patentable—speed instruction processing.

For example, when the Software Co-Processor sees repetitive program structures, such as loops, it decodes their instructions only once. Thus, the translation software doesn't have to reinterpret the instructions when it encounters the loop again in the MS-DOS software.



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As a result, the software requires the target computer to run through only about eight to 10 target  $\mu$ P instructions to interpret each 8086 instruction.

The third software solution is Hunter Systems' XDOS, which is now undergoing final debugging. Rather than interpreting or translating 8086 instructions, the XDOS program converts the 8086's instructions to equivalent instructions for the target  $\mu$ P. Thus, before you run an MS-DOS-based program on your target computer, XDOS performs a binary-to-binary conversion that compiles the 8086 instructions into your target  $\mu$ P's instructions. Industry experts agree that the conversion approach is a very difficult challenge, but because the computer spends no time interpreting instructions as the application program runs, MS-DOS-based application programs should run faster

than they would under SoftPC or Software Co-Processor. However, keep in mind that each 8086 instruction compiles into an average of one and a half to two of the target computer's instructions. The compilation doesn't yield a 1-to-1 op-code-to-op-code translation ratio.

## 32 bits are a must

To be practical, all three software solutions require the processing speeds and memory capacities that today's 32-bit  $\mu$ Ps furnish. With anything less than a 32-bit  $\mu$ P in your target computer, execution speeds for converted or interpreted MS-DOS programs will drag when you compare their execution speed to what you'd expect from an IBM PC/XT, PC/AT, or a compatible computer. The translation programs require 32-bit-wide memory simply to hold their simulation software efficiently. For example, In-

signia's software needs 3.5M bytes of memory in your target computer system.

Even the XDOS program requires about 100k bytes. Although it converts the 8086 instructions prior to running the program, it still must simulate the IBM PC's MS-DOS configuration for the program's use. Trials show that because XDOS requires a relatively small amount of memory, you can run it on powerful 16-bit  $\mu$ Ps, such as Motorola's 68010.

## Cost is nominal

Fortunately, the cost of adopting these software techniques isn't high, at least not when compared with the \$5000 to \$50,000 necessary for a typical 32-bit Unix-based workstation or computer. Likewise, they're less expensive than plug-in boards that simulate the IBM PC's hardware.

## The IBM PC aberration

In the ideal 32-bit computer world, there would be no need for software-translation programs. Unix would be the universal standard operating system, and all programs would be written in C so that you could run them on any Unix system. Thus all  $\mu$ Ps would only be given a Unix operating system and a C compiler, and they would all be equal from the standpoint of software support.

But today the Intel 80386  $\mu$ P has an advantage over all other 32-bit  $\mu$ Ps, because it enjoys the heritage of what some call the IBM PC aberration. Just as the 16-bit members of the 8086 family gained an overwhelming dominance in the 16-bit arena because of the PC's popularity, so could the 80386 become dominant in the world of 32-bit computers. The basis for the dominance is the 50,000-or-so programs written by third-party software developers for the IBM PC. If you want to view the magnitude of the software-development effect, just look on the shelves in your local software store or in the advertisements in personal-computer magazines. If you are concerned with designing embedded systems, just look at the many varied libraries of specialized MS-DOS-based software for industrial and scientific applications.

Most of these MS-DOS programs were written

in 8086 or 8088 assembly language so you can use them only on computers equipped with 8086-family  $\mu$ Ps. Typically, when such programs have been written in a high-level language, the supplier will not release the high-level-language source code. That leaves you without an easy conversion route to another  $\mu$ P family.

You can argue that the ideal Unix- and C-based 32-bit world has indeed arrived. There are as many Unix-based personal computers now as any Unix visionary could have ever wished for. But the MS-DOS-software market dwarfs efforts on Unix's behalf. That in itself might not be a problem if it weren't for the third-party software developers who tend to write software for computers with a large market share. The software on the retail shelves bears this out. Buyers follow suit, buying software for the most popular computers.

So, because the software-translation techniques let other  $\mu$ Ps share MS-DOS-based software, they may get OEM designers past the IBM PC aberration. Now designers can choose  $\mu$ P hardware based on its own technical merits and suitability for an application while still maintaining compatibility with the MS-DOS software world.



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Insignia plans to sell its SoftPC packages through distributors for \$595. The SoftPC package runs on either a SUN-3 or on an Apple MAC-II computer, both of which use the 68020  $\mu$ P. Hunter Systems and Phoenix plan to work with OEMs, but both say that their packages will cost about the same as Insignia's software. In some cases you won't have to buy the translation software. NCR (Dayton, OH) is considering bundling such programs with its 68020/30-based Tower computer system.

These software-translation packages also have other advantages. For example, when you run MS-DOS-based software on a Unix-based computer system, the MS-DOS software can capitalize on the Unix system's resources. Thus, not only is extensive multitasking possible, but so are multiuser and file-sharing operations. Also, such Unix-based systems are often ahead of the IBM PC when it comes to providing user-friendly mouse and graphics interfaces.

However, the layered Unix software can slow your computer. The

interpretive approaches to converting MS-DOS-based software, while fine for single-user computers, may bring multiuser-Unix systems to a halt. Performance depends to a great extent on the target system's  $\mu$ P. **Table 1** provides a preliminary look at the reported and projected performances of these systems in terms of the Dhrystone benchmark. Use the results with much caution. More accurate data will emerge as more users adopt these software-translation techniques.

First, to provide a basis of comparison, **Table 1** lists benchmark values for the 8088, 80286, and 80386  $\mu$ P in familiar computers. The original IBM PC and the later PC/XT use 8088s that run at 4.77 MHz. An Intel representative says that the company's benchmark tests yield about 400 to 500 Dhrystones for both computers.

The IBM PC/AT yields a wide range of Dhrystone rates because a wide range of clock speeds is now used in PC/AT and compatible computers. There are two sets of Dhrystone values for the 80386. The first, 6000 to 7000 Dhrystones, re-

sults from running 16-bit 8086 code on the 80386. The second set, 9000 to 10,000 Dhrystones, arises when the 80386 runs full 32-bit code. The 80386 can run either type of code directly because the instruction bit patterns are identical. Keep in mind that, when the 80386 runs 8086 code from within the 80386's protected mode, there is an additional 20% or so degradation in performance because the 80386 must trap the 8086's memory and I/O instructions to protect the system.

**Table 1** also supplies Dhrystone values for non-8086-family target  $\mu$ P as they run the Dhrystone program—in both target  $\mu$ P code and in 8086 code that runs through a translation program. The non-8086  $\mu$ P fall into two categories: reduced-instruction-set computers (RISCs) and complex-instruction-set computers (CISCs).

When a 68020 (16 MHz) runs an MS-DOS Dhrystone program for an 8086  $\mu$ P by way of the Phoenix or the Insignia translation method, you reap about the same performance as you would from a PC/XT: 500 Dhrystones. A 68030 (25 MHz)

**TABLE 1—ROUGH BENCHMARK COMPARISONS FOR SOFTWARE-TRANSLATION TECHNIQUE**

$\mu$ P	CLOCK FREQUENCY (MHz)	OPERATING SYSTEM	COMPUTER	TRANSLATION TECHNIQUE	8086 CODE (DHRYSTONES) <sup>1</sup>	NATIVE CODE (DHRYSTONES) <sup>1</sup>
8088	4.77	MS-DOS 2.3	PC/XT	NONE	400 TO 500	400 TO 500
80286	6 TO 12	MS-DOS	PC/AT <sup>2</sup>	NONE	1000 TO 2000	1000 TO 2000
80386 <sup>3</sup>	20	MS-DOS 3.3	COMPAQ DESKPRO	NONE	6000 TO 7000	9000 TO 10,000
68020	16	UNIX	SUN-3	SOFTWARE CO-PROCESSOR SOFTPC	500 TO 2000	6000 TO 8000
68030	25	UNIX	SUN-3	XDOS	2000 TO 3000	6000 TO 8000
68020	16	UNIX	SUN-3	XDOS	2000 TO 3000	6000 TO 8000
68030	25	UNIX	SUN-3	XDOS	2000 TO 3000	6000 TO 8000
32532	20 TO 30	UNIX	GENERIC ADD-IN CPU BOARD	SOFTWARE CO-PROCESSOR	1000 TO 4000 <sup>4</sup>	9000 TO 16,000
CLIPPER (C-100 AND C-300)	33 TO 50	UNIX V.3	INTERPRO SERIES	SOFTPC	1000 TO 3000 <sup>4</sup>	8000 TO 16,000
CLIPPER (C-100 AND C-300)	30 TO 50	UNIX V.3	INTERPRO-200	XDOS	5000 TO 10,000 <sup>4</sup>	8000 TO 16,000
MIPS R2000		UMIPS/UNIX	M/1000	SOFTPC	3000 TO 5000 <sup>4</sup>	24,000

**NOTES:**

1. USE BENCHMARKS WITH CAUTION.
2. PC/AT SPEEDS DEPEND ON COMPUTER MODEL AND MANUFACTURER.
3. EXPECT A 20% DEGRADATION WHEN USING THE 80386 IN PROTECTED MODE.
4. TENTATIVE VALUES BASED ON MANUFACTURERS' PROJECTIONS.



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should operate at about 2000 Dhrystones—the performance of today's PC/AT.

Preliminary tests indicate that when the same 68020-based computers use the XDOS translation software, they should reach or exceed PC/AT performance. Typically, a 68020  $\mu$ P would be running under Unix in a computer such as the SUN-3 workstation.

One of the fastest CISC  $\mu$ P's is National Semiconductor's 32532. The company claims that the device reaches an operating clock frequency of 30 MHz. Based on that clock frequency, Phoenix's Software Co-Processor should run MS-DOS-based software at about twice the speed of a PC/AT. Table 1 also provides some speculative estimates of performance levels for two RISC  $\mu$ P's: Intergraph's Clipper and MIPS's R2000. The estimates include SoftPC estimates for both RISC  $\mu$ P's and an XDOS estimate

## For more information . . .

For more information on the software packages discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or contact the following manufacturers directly.

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**Insignia Solutions Inc**  
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San Francisco, CA 94109  
(415) 885-4455  
Circle No 717

**Phoenix Technologies Ltd**  
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for the Clipper. The technical marketing staffs at both Intergraph and MIPS helped prepare the estimates.

Assuming that future performance matches that which the RISC suppliers promise—they talk of reaching 50 MIPS by the early 1990s—it may be that RISC  $\mu$ P's will be attractive for running MS-DOS-based programs that can benefit from high execution speeds. But keep in mind that by definition RISC machines tend to use more

instructions than do CISCs. So although they operate faster, they require more instructions. Also, you can assume that Intel will continue expanding the capabilities of its 8086 family. Intel has broadly hinted that the future 80486  $\mu$ P will offer faster, more RISC-like instructions. Thus, instead of the 80386's average 4.4 clock cycles per instruction, the 80486 may require just two clock cycles.

So, at least, these software-trans-

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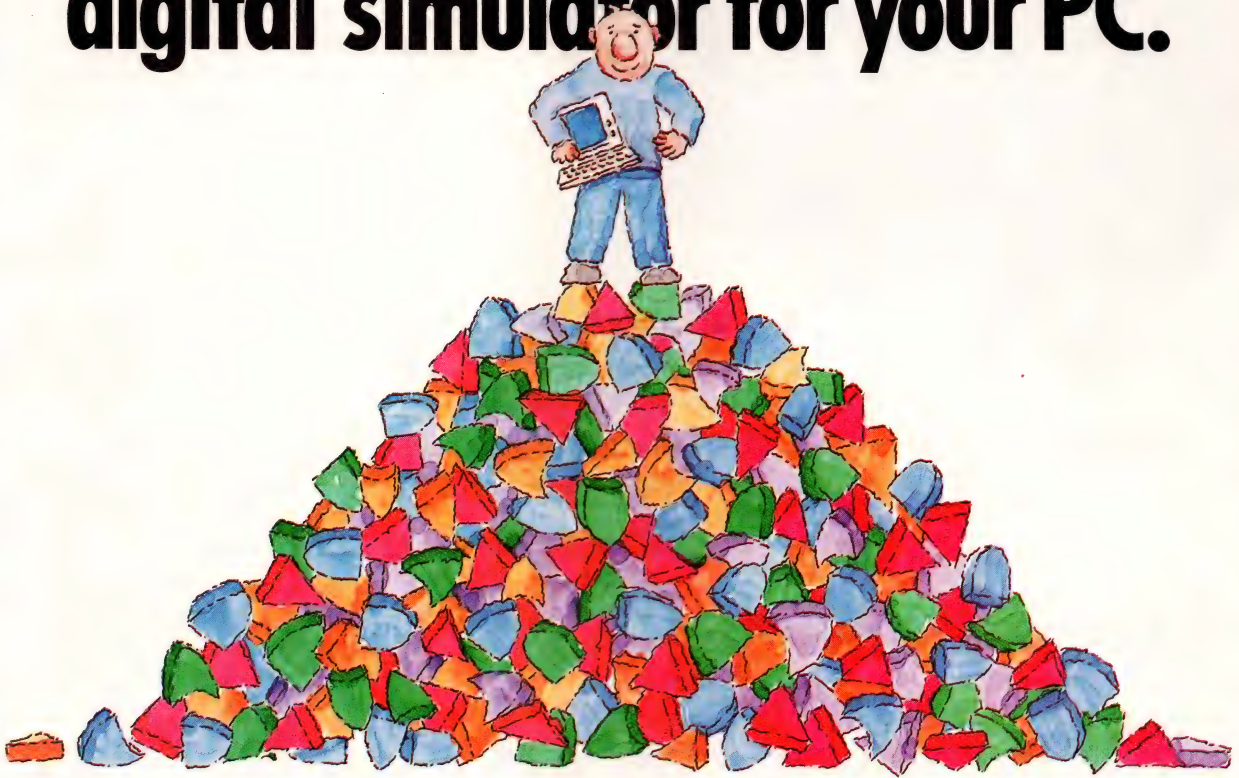
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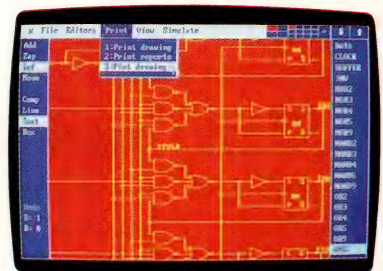
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lation techniques will run MS-DOS-based 8086 code on 32-bit computers as fast as it runs on IBM PCs and PC/XTs. At most, the techniques promise to run MS-DOS-based programs much faster than they run on present, or will run on near-future 8086-family  $\mu$ Ps. But no one expects these techniques to upset the 8086; as Intel points out, these imitators will always be behind the 8086 family when it comes to software timeliness. After all, the MS-DOS-based software is really meant for use on 1981-vintage hardware, says Intel. What will soon count in the 32-bit computer world is how well the computers run 32-bit software, not how well they run old 16-bit programs.

However, the software-translation techniques can add immediate value to new RISC  $\mu$ Ps such as AMD's 29000. New  $\mu$ P-chip manufacturers cannot offer libraries of software products as soon as their chips are available. So, the ability to run existing MS-DOS-based programs can help such chips survive while their supporters build up a repertoire of 32-bit software.

#### Remember embedded systems

At first glance, these software-translation approaches appear to benefit only desktop workstations and similar large computers. Designers of embedded systems will also find them useful, particularly the XDOS binary-translation approach, because it demands little additional memory. One example is when an OEM designer wants to place a specialized MS-DOS-based program for laboratory-data analysis into an embedded controller as an option for customers. Being able to select an MS-DOS-based program for a non-8086-family computer opens a world of possibilities.

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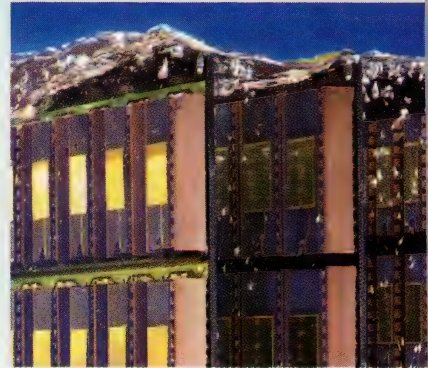
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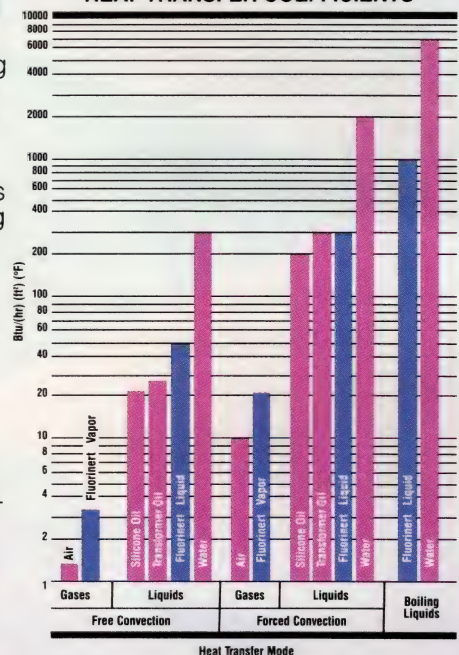
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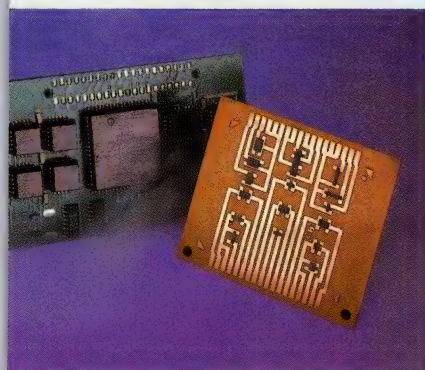


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- Radar klystrons • Computer modules
- Computer memories • Fuel cells

Typical properties of Fluorinert Liquids used in cooling are:

Fluorinert Liquid FC-77 (English Units)	Liquid		Vapor
	Room Temp. (77°F)	Boiling Point (207°F)	Boiling Point 207°F @/ATM
Density lb./ft <sup>3</sup>	111	100	0.85
Thermal Conductivity Btu/(hr) (ft <sup>2</sup> ) (°F/ft)	0.037	0.033	0.008
Specific Heat Btu/(lb.) (°F)	0.25	0.28	0.23
Viscosity c.p.	1.42	0.46	0.02
Coefficient of Thermal Expansion ft <sup>3</sup> /(ft <sup>3</sup> ) (°F)	0.0008	0.0009	0.0015

#### Discover heating/curing with Fluorinert™ Liquids

Because they maintain their vapor temperature with absolute precision, Fluorinert Liquids can be used in many heating and/or curing operations. They serve as heat transfer media in solder mask and polymer thick film applications and for polymer processing. The non-corrosive vapors will not support oxidation. Ideal where solvent flash-off is a problem.

SEE US AT NEPCON-WEST, BOOTH 241

**3M**



# Discover Fluoronics Resources

**3M presents a unique short course in the use of Fluorinert™ Liquids for the electronics industry.**

3M is now offering a series of "Applied Fluoronics" tapes demonstrating how Fluorinert Liquids are used in a number of applications. See first hand how these remarkable products can improve overall electronic production.

Three cassettes are available:

1. "Applied Fluoronics: High Reliability Testing"
2. "Applied Fluoronics: Vapor Phase Soldering"
3. "Applied Fluoronics: Direct Contact Cooling"

These informative VHS format tapes are available to qualified personnel in the electronics industry. Specify which cassette(s) you would like to view.

Write on your company letterhead, describing your general interest. Mail to: Fluoronics Resources, Industrial Chemical Products Division/3M, Building 223-6SE-04, 3M Center, St. Paul, MN 55144-1000.

For technical information or assistance on High Reliability Testing and Cooling, call 612/733-6282; for Vapor Condensation Heating assistance, call 612/733-7424.



# 3M



## Buscon/88 West offers technical programs, seminars, and presentations galore

All computer-bus users should put Buscon/88 West high on the list of shows and conferences they plan to attend. As in the past, the Buscon program offers training seminars and technical presentations, as well as commercial exhibits. Running from February 22 to 25 at the Disneyland Hotel in Anaheim, CA, Buscon has eight seminars for you to choose from. Four of the seminars run for a full day, but the other four are only a half day each.

One of Monday's full-day seminars is entitled "A technical look at bus structures and applications," and will give you a working knowledge of general bus structures in addition to an overview of today's popular buses and emerging bus technologies for future use.

If you'd rather spend your time taking a closer look at the Nubus, however, then attending "The Nubus; and a special Macintosh II-Nubus workshop" may be a day well spent. The morning portion of the seminar covers technical aspects of the Nubus's architecture. You'll learn about the bus's performance, its processor and architecture orientation, and how the bus supports multiprocessor operations. In the afternoon session, you'll learn about Apple's Mac II computer and how it implements the Nubus's architecture. Seminar leaders will also discuss the market for Mac II-compatible hardware.

For Multibus II users and Multibus II OEMs, another Monday seminar, "Designing with the message-passing coprocessor," will supply information about how to design with and use the chip. During the discussions of message-passing coprocessor applications, the seminar

leader will also discuss topics ranging from bus basics to hardware and software development.

However, if you're already firmly in the VME Bus camp, "Choosing and using the new generation of VME Bus interface chips" may be more to your liking. The Monday-afternoon seminar will present the similarities and differences between the VME Bus interface chips that will soon make their debut. In this session, you'll also hear about guidelines that can help you determine which chip approach is best for your application. The seminar will include examples of pc-board designs that include the new VME Bus interface chips.

Another Monday-afternoon seminar will discuss the problems of designing a compatible product for IBM's Micro Channel architecture. Monday's technical seminars wind up with an afternoon session devoted to the VSB—a subset of the VME Bus. The VSB (VME Subsystem Bus) provides an alternative for data-transfer operations between multiple processors in a VME Bus computer system.

The seminar sessions also include two nontechnical programs. Monday's fourth all-day session affords you the chance to learn about selecting a manufacturer's representative, and Tuesday's schedule includes an all-day program devoted to partnership opportunities for US and Japanese companies.

Aside from the seminars, you can also attend technical programs on Tuesday, Wednesday, and Thursday at the Disneyland Hotel. The technical programs offer topics that will interest most bus users. You'll get a choice of hardware and soft-

ware presentations ranging from interface designs and bus structures to real-time operating systems and multiprocessing applications.

If you'd rather peruse the bus manufacturers' latest hardware and software products, Buscon won't disappoint you. The show has reservations for over 200 booth spaces in the Disneyland Hotel's exhibit area. The exhibits will be open on February 24th between 11 am and 5:30 pm, and also on the 25th between 11 am and 4:30 pm.

As in the past, Buscon's organizers (CMC, Norwalk, CT, (203) 852-0500 or (714) 669-1201) plan a traditional Buscon party on the exhibit floor. Billed as the "all-aboard" industry reception, the get-together starts at 5:30 pm on Wednesday. Attendance is by invitation only, but the Buscon committee has a loose interpretation of what constitutes an invitation. No other show offers such an opportunity to visit with company marketing, sales, and technical people in such a relaxed, informal setting.

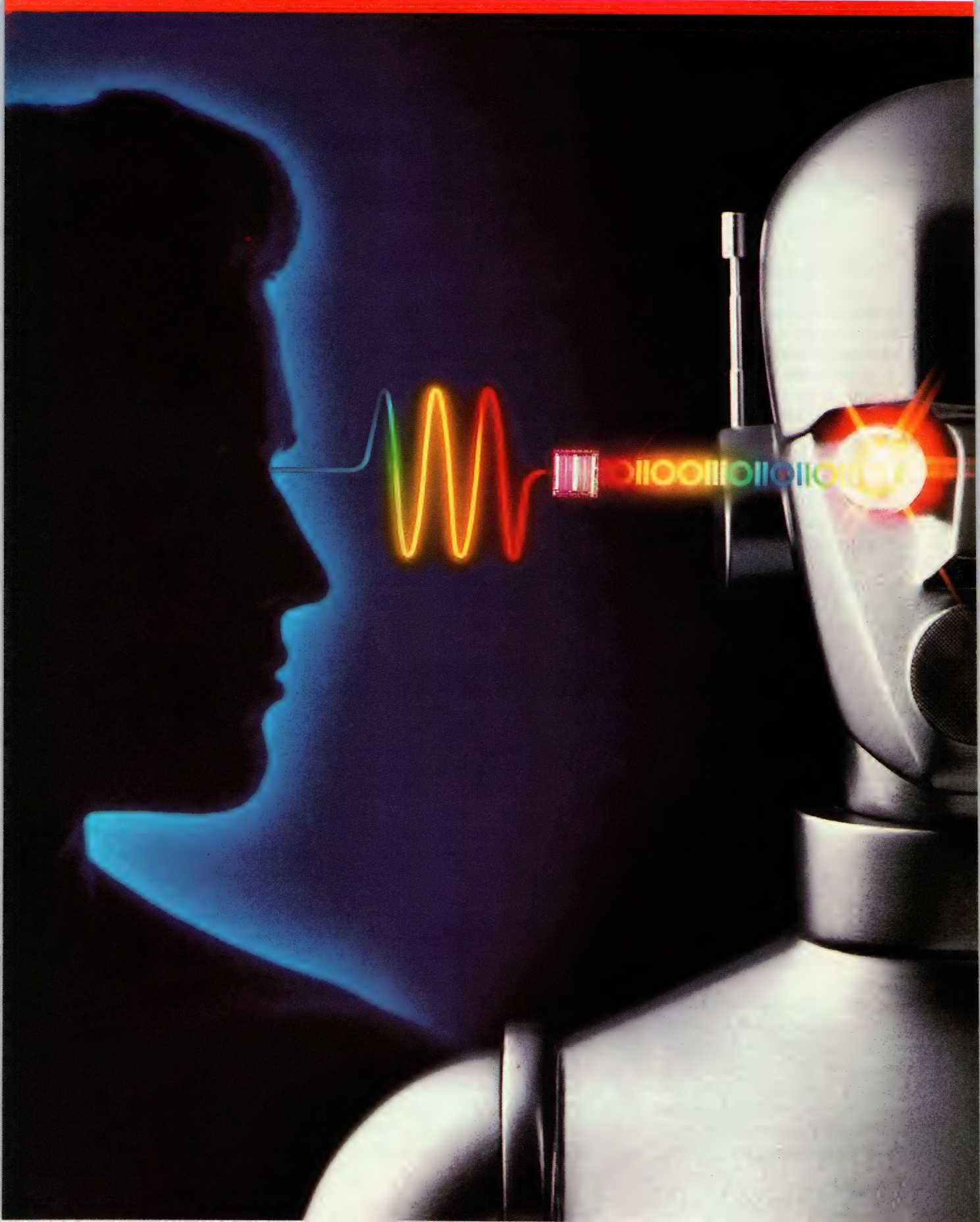
At the last Buscon show in the Boston area, the conferences, seminars, and exhibits drew approximately 2000 people. This winter, Buscon's organizers project attendance of at least 3000 participants. The Buscon show is small when you compare it to Wescon, Electro, or Comdex, but there's no better place to meet other bus users and industry experts.—*EDN Staff* **EDN**

Article Interest Quotient  
(Circle One)

High 506 Medium 507 Low 508



# High-resolution conversion





# in the blink of an eye.

## Get video speed, low power consumption, high resolution and superior price/performance with our new CMOS data converters.



We've expanded our line to include more CMOS flash ADC's, a charge balancing ADC, an SPI ADC and a DAC. All featuring single 5V supply operation.

We also offer a new high-speed op amp especially well-suited to driving ADC's or video cables.

### 4, 6 and 8-bit CMOS flash ADC's.

Choose from 4, 6 and 8-bit ADC's. All operate at video speeds, with clocking speed and input bandwidth specified at 5V. What makes these flash ADC's special is silicon-on-sapphire construction, resulting in low cost, high speed, very low input capacitance, low power consumption and inherent latch-up resistance.

### 10-bit CMOS charge balancing ADC.

This 10-bit successive approximation ADC captures fast moving signals, providing excellent resolution.

It features a built-in fast track and hold, with conversion rates of 150 KHz and an input bandwidth of 1.5 MHz. Even at the maximum rate, power consumption is less than 20 mW.

### 10-bit CMOS serial ADC.

The CDP68HC68A2 is selectable for either 8- or 10-bit resolution and has an 8-channel multiplexer allowing up to 8 channels of inputs. The device can be used directly with our CDP68HC05C4, C8 or D2 microprocessors or other similar SPI (Serial Peripheral Interface) buses.

### 8-bit CMOS R-2R video-speed DAC's.

These CMOS/SOS digital-to-analog converters operate

from a single 5V supply at video speeds and can produce "rail-to-rail" output swings. Typical update rate is 50 MHz. Settling is fast (20 ns typical) to 1/2 LSB. "Glitch" energy is minimized by segmenting and bar graph decoding of upper 3 bits.

### High-speed op amp.

Specially designed for use with data converters, the CA3450 op amp has excellent speed and transmission line driving capabilities.

For 10-bit accuracy, it settles to within 1/2 LSB in 40 ns with a 2V input signal. And it can drive up to four 50 ohm transmission lines.

ADC's	Res. Bits	Conv. Rate Hz	Power Diss. (mW)	Pkg. Leads	1K Price
CA3304E	4	20M	30	16	2.95
CA3304AE	4	25M	35	16	4.50
CA3306CE	6	10M	65	18	5.50
CA3306E/3306AE	6	15M	70	18	6.25/11.25
CA3318E/3318CE	8	15M	150	24	38.50/24.00
CA3310E/3310AE	10	150K	15	24	6.00/8.00
CDP68HC68A2E	10	10K	15	16	3.75
DAC's					
CA3338E/3338AE	8	50M	100	16	6.00/8.40
OP AMP	UGBW Hz	Slew Rate (X10)	I <sub>OUT</sub> MA	Pkg Leads	1K Price
CA3450E	200M	300V/μSec	±75	16	2.70

### Data in a flash.

For data sheets of these new products, call toll-free 800-443-7364, extension 19. Or contact your local GE Solid State sales office or distributor.

In Europe, call: Brussels, (2) 246-21-11; Paris, (1) 39-46-57-99; London, 0276-685911; Milano, (2) 82-291; Munich, (89) 63813-0.



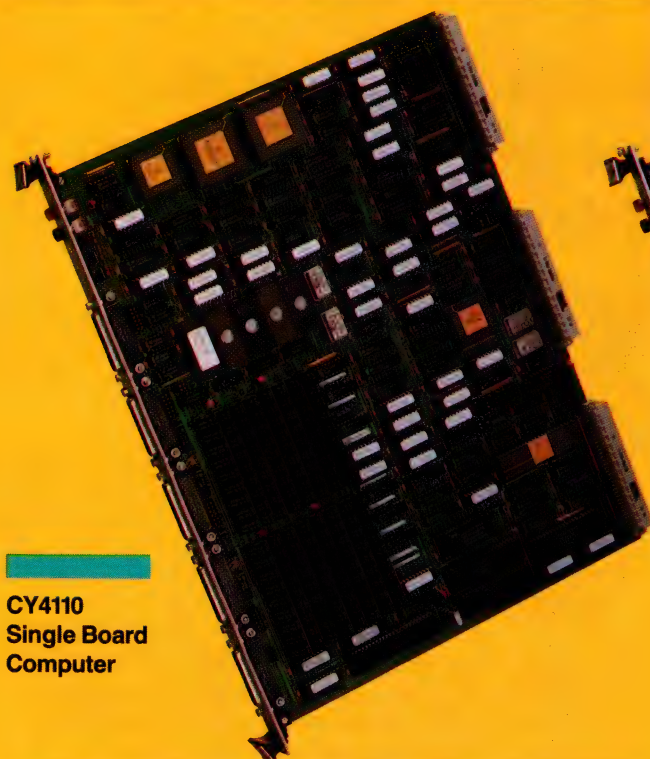
**GE Solid State**

### GE/RCA/Intersil Semiconductors

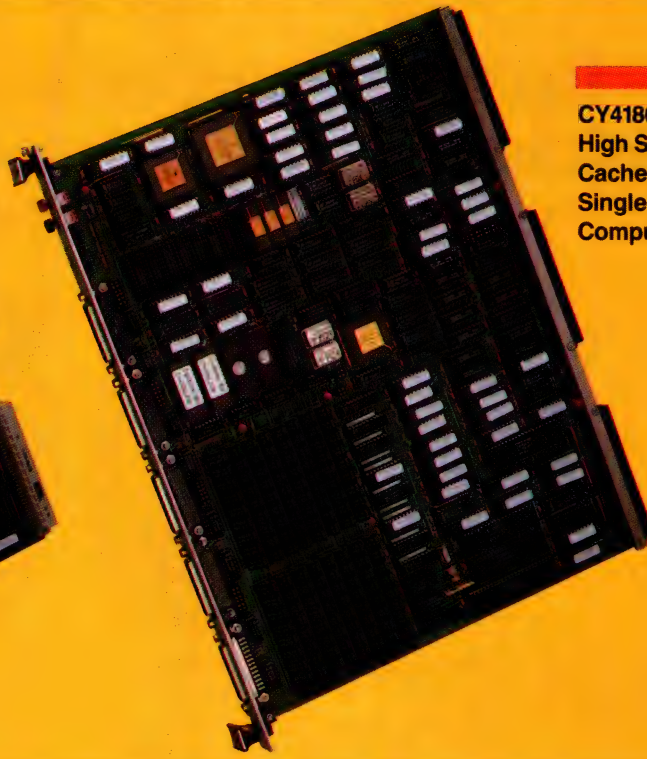
These three leading brands are now one leading-edge company. Together, we have the resources — and the commitment — to help you conquer new worlds.



# Embedded Power



**CY4110**  
Single Board  
Computer



**CY4180**  
High Speed  
Cache Memory  
Single Board  
Computer

## Cyclone Microsystems' VME Single Board Computers can accelerate your system development with a growing family of highly integrated embedded computers.

Our VME Single Board Computers feature a 68020 with co-processors supported by extensive memory, disk controllers, DMA, serial and parallel I/O.

The CY4110 and CY4180 Single Board Computers offer system designers the benefits of a highly integrated system coupled with the advanced performance of extensive local resources. Resources like a zero wait state cache, up to 16 Mbytes of dual ported DRAM, VSB Interface, and SCSI.

Product development is enhanced by our support of the PDOS™ and OS-9™ Real Time Operating Systems.

Accelerate your next system design with a powerful Single Board Computer packed with functionality. Call us at (203) 786-5536. And discover what our embedded power can do for your next system.

**CYCLONE**  
**MICROSYSTEMS**

25 Science Park, New Haven, CT 06511  
(203) 786-5536 FAX (203) 786-5023  
TELEX 643998

Features	CY4110	CY4180
MC68020 CPU	Up to 20 Mhz	Up to 25 Mhz
MC68851 Paged Memory Mgt.	Optional	
MC68881 Floating Point	Optional	Optional
16K Cache Memory		Zero Wait State
DRAM	2,4,8 or 16 Mbytes	2,4,8 or 16 Mbytes
ROM/SRAM	256K	256K
DMA Controller	Two Channel	Two Channel
SCSI	1.5 Mybtes/sec	1.5 Mybtes/sec
Floppy Disk Controller	Yes	
RS-232-C	4 Ports	4 Ports
Parallel	1 Port	1 Port
VME Master/Slave	A32, D32	A32, D32
VSB Interface		Master
Counter timer	24 bit	24 bit
Interrupts	18 Sources	18 Sources
Form Factor	9U x 280mm	9U x 280mm

PDOS is a trademark of Eyring  
OS-9 is a trademark of Microware



# BOURNS

## SMD

# SURVIVAL GEAR.



Surface mount technology has assumed a strategic role in electronics.

To survive in the marketplace, more and more products need the cost savings, space efficiency and high performance of the surface mounted designs you're creating today.

When your circuits call for surface mounted trimming potentiometers and resistor networks, the answer is Bourns. Survival gear.

### Customerized Technology: The Bourns Advantage

Bourns—more than any other resistive component manufacturer—has taken surface mount technology and optimized it to your manufac-

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catalog with easy-  
to-use selection  
guide available  
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local office for  
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turing processes. We call it "customerized technology" and it means that you can be sure our components will work smoothly with your onsertion equipment; that it will stand up to the new—and hotter—SMD soldering techniques; and, that they will survive vigorous boardwashing. Customerized technology means that before we

design our product we even take into consideration how you test the board.

### There's No Equivalent

Today you can select from more than 15 styles from Bourns Trimpot including the new 3304, the first 4mm model that's both SMD compatible and automation friendly.

Bourns has also developed an extensive line of surface mount resistor networks. Included in the line are both molded PCC, SOIC, and now SOJ styles in standard JEDEC packages. All in all, nobody serves up SMD technology in so many ways.

Bourns always makes the extra effort. There's no equivalent.

## NOW! Anti-Tombstoning Chip Resistors

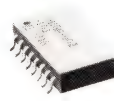
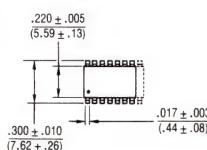
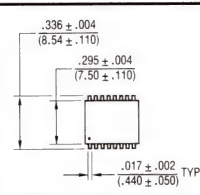
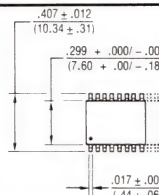
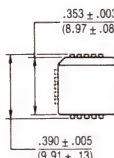


**BOURNS TRIMPOT  
BOURNS NETWORKS**

*After 40 years, there's still no equivalent.*

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**BOURNS****Resistor Networks****Molded PCC****MODEL 4200P****Molded SOL****MODEL 4400P****Molded SOL-J****MODEL 4400J****SOM****MODEL 4800P****Board Space****Style**

Leaded Chip Carrier

Wide Body Gull Wing

Wide Body "J" Lead

Medium Body Gull Wing

**Pin Counts**

10 and 20

16 and 20

16 and 20

14 and 16

**Packaging**Plastic tubes,  
tape and reelPlastic tubes,  
tape and reelPlastic tubes,  
tape and reelPlastic tubes,  
tape and reel**Standard Resistance Range (Ohms)**

10Ω to 1 Megohm

10Ω to 1 Megohm

10Ω to 1 Megohm

10Ω to 1 Megohm

**Maximum Operating Voltage**

50V

50V

50V

50V

**Temperature Coefficient of Resistance**± 100ppm/°C  
± 250ppm/°C for  
values less than 50Ω± 100ppm/°C  
± 250ppm/°C for  
values less than 50Ω± 100ppm/°C  
± 250ppm/°C for  
values less than 50Ω± 100ppm/°C  
± 250ppm/°C for  
values less than 50Ω**Operating Temperature**

-55°C to +125°C

-55°C to +125°C

-55°C to +125°C

-55°C to +125°C

**Power Rating**Derate to zero power  
+70°C to +125°CDerate to zero power  
+70°C to +125°CDerate to zero power  
+70°C to +125°CDerate to zero power  
+70°C to +125°C**Power Dissipation**4210P ..... 0.160  
watt/resistor  
1.50 watts/package  
  
4220P ..... 0.115 to  
.160 watt/resistor  
2.00 watts/package4420P ..... 0.115 to  
.200 watt/resistor  
2.0 watts/package  
  
4416P ..... 0.115 to  
.200 watt/resistor  
1.6 watts/package4420J ..... 0.115 to  
.200 watt/resistor  
2.0 watts/package  
  
4416J ..... 0.115 to  
.200 watt/resistor  
1.6 watts/package4814P ..... 0.080 to  
.200 watt/resistor  
1.12 watts/package  
  
4816P ..... 0.080 to  
.200 watt/resistor  
1.28 watts/package**Short Time Overload (ΔR Max.)**

± 0.25%

± 0.25%

± 0.25%

± 0.25%

**Load Life (ΔR Max.)**

± 1.00%

± 1.00%

± 1.00%

± 1.00%

**Mechanical Shock (ΔR Max.)**

± 0.25%

± 0.25%

± 0.25%

± 0.25%

**Moisture Resistance (ΔR Max.)**

± 0.50%

± 0.50%

± 0.50%

± 0.50%

**Resistance to Soldering Heat (ΔR Max.)**

± 0.25%

± 0.25%

± 0.25%

± 0.25%

**Body Materials**

Epoxy resin/novolac

Epoxy resin/novolac

Epoxy resin/novolac

Epoxy resin/novolac

**Schematics**Isolated, Bussed,  
Dual TerminatorsIsolated, Bussed,  
Dual TerminatorsIsolated, Bussed,  
Dual TerminatorsIsolated, Bussed,  
Dual Terminators



# EDN

## SURFACE-MOUNT TECHNOLOGY

This Designer's Ready Reference chart provides a check list that you can use when you have completed your electronic design and are ready to pass the design on to a circuit-board engineer. Because there are many decisions you must make before a board can be laid out, you can use this check list to help prepare necessary design information.

### DESIGN RULES

- Type of design:
- SMT only
  - Mixed SMT and through-hole components
- Mounting:
- Component-side only
  - SMT solder-side only
  - Both sides

### DESIGN RULES FOR SMT COMPONENTS

CONFIGURATION	SPACING (IN.)	
	TYP	MIN
SOIC (SIDE TO SIDE)	0.100	—
SOIC (END TO END)	—	0.025
SOIC (SIDE TO CHIP)	0.050	—
SOIC (END TO CHIP)	0.050	0.025
PCC TO PCC	0.100	—
PCC TO CHIP	0.050	—
CHIP TO SOT	0.050	0.025
CHIP TO CHIP	0.050	0.025
LAND TO TRACE	0.008	—
TRACE TO TRACE	0.008	—
PAD TO TRACE	0.008	—
TRACE WIDTH INTO LAND	≤0.015	0.008
VIA PAD DIAMETER	0.037	0.025
VIA HOLE DIAMETER	0.020	0.013
PCC SOCKET CLEARANCE	0.200	—
LAND TO SILKSCREEN	—	0.010
TRACE TO BOARD EDGE	0.050	0.025
LAND TO WIDE TRACE	0.025	0.0125
TRACE WIDTH	0.008	—
VIA TO UNRELATED LAND	0.025	0.008

### DESIGN RULES FOR MIXED TECHNOLOGY

CONFIGURATION	MIN SPACING (IN.)
CHIP TO AXIAL LEAD	0.075
CHIP TO AXIAL BODY	0.050
SOIC TO DIP	0.100
AXIAL SIDE TO DIP SIDE	0.100
AXIAL END TO DIP END	0.200
DIP END TO DIP END	0.200
DIP SIDE TO DIP SIDE	0.100
SOIC SIDE TO DIP SIDE	0.100
PCC TO DIP SIDE	0.125
PCC TO AXIAL BODY	0.100

### DESIGN REQUIREMENTS FOR TEST

All test pads should be accessible from the same side of the board; usually the bottom.

The test pads should be at least 0.035 in. in diameter.

As many of the test pads as possible should be put on 0.100-in. centers.

The minimum space between test pads cannot be less than 0.050 in.

If the board tester supplies power to your circuit through test pins, use at least one test pad for each ampere of power. Thus, 5V at 1A requires one test pad for the power and one for the ground connection.

All interconnect networks should have a test pad.

Determine whether you need access to unconnected or disconnected IC pins for testing purposes.

Test pads must be separated from the component lands.

### MANUFACTURING

Identify the types and models of the machines used for pick-and-place operations.

Which solder-reflow method will be used?

- Infrared
- Laser
- Vapor phase
- Hand solder
- Wave solder
- Hot air

Which type of cleaner will you use?

- Aqueous
- Solvent
- Spray
- Manual

Can selected components withstand manufacturing-process stresses?

What is the panel or board size you require?

Can you use a standard board or panel size?

What are the tooling specifications for assembly machines?

What will be the board's orientation?

What are the component orientations?

Are there any autoinsert or autoplacement guidelines?

What are the edge clearances for wave soldering and for autoinsertion?

### LAYOUT DETAILS

What is the maximum acceptable number of layers?

Do all components have designators and pins assigned to them?

Has the power-and-ground table been completed?

Have the critical-signal paths been identified?

Have the components that dissipate more than 1W been identified?

Where must the power-supply bypass capacitors be placed?

### BILL-OF-MATERIAL INFORMATION

Are all designators, part numbers, and quantities included?

- Are capacitor values listed in  $\mu$ F or pF units?
- Are the capacitor's working voltages specified?
- Are the capacitor's tolerances specified?
- Are the capacitor's dielectric materials specified?
- Are all resistor wattages specified?
- Are all resistor tolerances specified?
- Can multiresistor packages be split into individual resistors?
- Are inductor values, tolerances, and voltages specified?
- Are shielded and unshielded inductors clearly marked?
- Are connector specs included?
- Are connector pin assignments clearly identified?
- Are any ICs to be butt mounted?
- Can multidevice ICs be repackaged?
- Are all socket-mounted items clearly identified?
- Are crystals to be grounded?
- Are specifications included for all nonstandard parts?
- Have you included specs for hardware items?

### TESTING

What is the minimum space needed between components for testing purposes?

What is the minimum test-pad size?

Are you using single- or double-side testing?

Will you be probing the top or bottom side of the board?

If bareboard testing is required, what is the grid spacing?

What bareboard test fixture will you use?

Is in-circuit testing required?

- If so, what is the grid spacing?
- Will the design use lands or separate pads for test?
- Must you probe disconnected pins on ICs?
- What in-circuit test fixture will be used?

Do you require functional testing?

### CIRCUIT-BOARD FABRICATION

How many layers will the board have?

Are there power and ground planes?

What is the board material's thickness; .030 in., .047 in., .062 in., or other?

Is a silkscreen required?

- What size letters are necessary?
- Which board sides will require silkscreen legends?

What is the copper-plating process?

- Solder mask over bare copper (smobc)
- Smobc with tin plate
- Solder mask over tin plate

What is the solder-mask process?

- Wet or dry film
- Color mask

If gold plating is required, what is the plating's thickness?

Is partial gold plating required?

### MECHANICAL





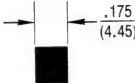

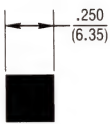
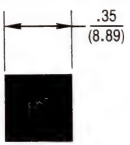
What is the board's size?

Are there any irregular cutouts?

Mechanical-drawing information:




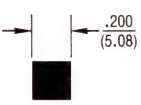
- Are edge connectors shown?
- Is a pin-1 designation clearly noted for each connector?
- Are tooling holes located by dimensions or are they located on a panel?
- Is panelization required? If so, what size panel do you need?
- Is palletization required? If so, what size pallet do you need?
- How many tooling holes are required and what are their dimensions (in inches)?



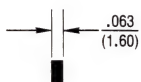
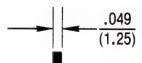
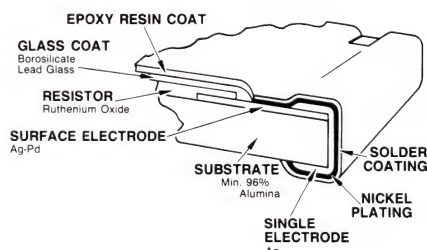


<div> <div>BOURNS</div> <div>Trimming Potentiometers</div> </div>	4mm Square Sealed Single-Turn	4mm Square Open Style Single-Turn	1/4" Square Sealed Multiturn	.350" Square Sealed Multiturn
	 <div>MODEL 3314</div>	 <div>MODEL 3304</div>	 <div>MODEL 3269</div>	 <div>MODEL 3272</div>
Board Space				
Configuration	J-Hook, Gull Wing	Leadless Chip	Gull Wing	Gull Wing
Adjustments	Top	Top	Top, Side	Side
Packaging	Embossed Tape	Embossed Tape	Plastic Tubes	Plastic Tubes (Embossed Tape Optional)
Body Dimensions	.244"x.197"x.100"	.15"x.18"x.094"	.25"x.25"x.28"	.35"x.35"x.20"
Standard Resistance Range (Ohms)	10Ω to 2 Megohms	500Ω to 1 Megohm	10Ω to 1 Megohm	100Ω to 1 Megohm
Resistance Tolerance (Std.)	± 20%	± 25%	± 10%	± 10%
Absolute Minimum Resistance (Max.)	1% or 2Ω (whichever is greater)	5%	1% or 1Ω (whichever is greater)	1% or 1Ω (whichever is greater)
Contact Resistance Variation (Max.)	1% or 3Ω (whichever is greater)	5%	3% or 3Ω (whichever is greater)	1% or 3Ω (whichever is greater)
Voltage Adjustability			± 0.02%	± 0.02%
Resistance Adjustability			± 0.05%	± 0.05%
Resolution	Infinite	Infinite	Infinite	Infinite
Insulation Resistance	200 vdc. 100 Megohms min.		500 vdc. 1,000 Megohms min.	500 vdc. 1,000 Megohms min.
Effective Travel			12 Turns nominal	12 Turns nominal
Maximum Exposure (Temperature/Time)	215°C/3 minutes 265°C/30 seconds 300°C/3 seconds	265°C/30 seconds	215°C/3 minutes	215°C/3 minutes
Power Rating	300 Volts max. 70°C.....0.25 watt 125°C.....0 watt	50 Volts max. 70°C.....0.2 watt	300 Volts max. 85°C.....0.25 watt 150°C.....0 watt	300 Volts max. 85°C.....0.25 watt 150°C.....0 watt
Temperature Range	- 55°C to + 125°C	- 55°C to + 125°C	- 65°C to + 150°C	- 65°C to + 150°C
Temperature Coefficient	+ 100ppm/°C	± 200ppm/°C nom.	± 100ppm/°C max.	± 100ppm/°C max.
Seal Test	85°C Fluorinert*		85°C Fluorinert*	85°C Fluorinert*
Mechanical Angle	240° nominal	Continuous	16 Turns nominal	16 Turns nominal
Torque	100G-CM max.	3.0 oz-in. max.	3.0 oz-in. max.	3.0 oz-in. max.
Terminals	Hot solder dipped copper		Solderable pins	Solderable pins
Weight	Approx. 0.01 oz.		0.015 oz.	0.02 oz.

\*Fluorinert is a registered trademark of 3M Company.



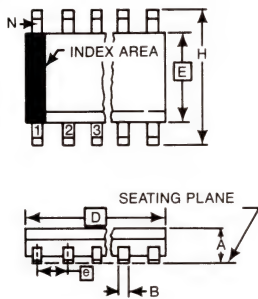
1/4" Square Sealed Single-Turn  <b>MODEL 3325</b>	5mm Square Sealed Single-Turn  <b>MODEL 3335</b>
	
"J" Leads, Gull Wing	"J" Leads, Gull Wing, Through-Hole
Top, Side	Top
Plastic Tubes	Embossed Tape
.35"x.26"x.22"	.20"x.20"x.16"
10Ω to 1 Megohm	10Ω to 500KΩ
± 10%	± 20%
1% or 2Ω (whichever is greater)	1% or 2Ω (whichever is greater)
1% or 3Ω (whichever is greater)	3% or 3Ω (whichever is greater)
± 0.05%	± 0.05%
± 0.15%	± 0.15%
Infinite	Infinite
500 vdc. 1,000 Megohms min.	500 vdc. 1,000 Megohms min.
215°C/3 minutes	215°C/3 minutes
300 Volts max. 35°C.....0.5 watt 150°C.....0 watt	100 Volts max. 85°C.....0.2 watt 150°C.....0 watt
- 55°C to + 150°C	- 55°C to + 150°C
± 100ppm/°C max.	± 100ppm/°C max.
85°C Fluorinert*	85°C Fluorinert*
260° nominal	270° nominal
3.0 oz-in. max.	3.0 oz-in. max.
Solderable pins	Solderable pins
0.02 oz.	0.02 oz.

<div><div><div>BOURNS</div></div><div>Chip Resistors</div></div>	<div>1/8 Watt</div> <div></div> <div>MODEL CR1206</div>	<div>1/10 Watt</div> <div></div> <div>MODEL CR0805</div>
Board Space		
Resistance Range (Ohms), Tolerance and Temperature Coefficient	<div>100Ω to 1 Megohm ± 1%, 100ppm/°C</div> <div>47Ω to 1 Megohm ± 5%, 200ppm/°C</div> <div>10Ω to 47Ω ± 5%, 300ppm/°C</div>	<div>47Ω to 1 Megohm ± 5%, ± 200ppm/°C</div> <div>10Ω to 47Ω ± 5%, ± 300ppm/°C</div>
Power Rating	0.125 watt	0.100 watt
Maximum Operating Voltage (at 70°C)	200 Volts	100 Volts
Maximum Ambient Temperature	125°C	125°C
Temperature Range	- 55°C to + 125°C	- 55°C to + 125°C
Thermal Shock (Method)	± 0.5% (MIL-R-55342, Para. 4.7.3)	
Low Temperature Operation (Method)	± 0.5% (MIL-R-55342, Para. 4.7.4/IS-30 Para. 3.6)	
Short Term Overload (Method)	± 0.5% (MIL-R-55342 Para. 4.7.5/IS-30 Para. 3.7)	
High Temperature Exposure (Method)	± 0.5% (MIL-R-55342 Para. 4.7.6/IS-30 Para. 3.8)	
<div>Body Materials</div> <div></div>		



EDN SURFACE-MOUNT TECHNOLOGY  
JEDEC PACKAGE SHAPES AND DIMENSIONS

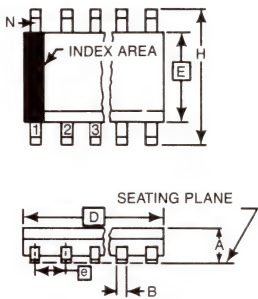
SMALL OUTLINE (SO)—0.50 IN. WIDE



SYMBOL	DIMENSIONS (IN.)	
	MIN	MAX
A	0.532	0.0688
B	0.0138	0.0192
E	0.1497	0.1574
e	0.050	0.050
H	0.2284	0.2440

NO OF PINS	D LENGTH (IN.)	
	MIN	MAX
8	0.1890	0.1968
14	0.3367	0.3444
16	0.3859	0.3937

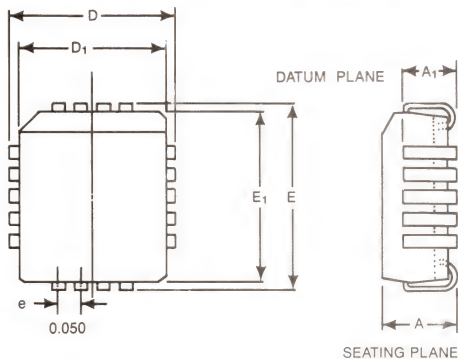
SMALL OUTLINE (SO)—0.300 IN. WIDE



SYMBOL	DIMENSIONS (IN.)	
	MIN	MAX
A	0.0926	0.1043
B	0.0138	0.0192
E	0.2914	0.2992
e	0.050	0.050
H	0.394	0.419

NO OF PINS	D LENGTH (IN.)	
	MIN	MAX
16	0.3977	0.4133
18	0.4469	0.4625
20	0.4961	0.5118
24	0.5985	0.6141
28	0.6969	0.7125

PLASTIC CHIP CARRIER (PCC), RECTANGULAR

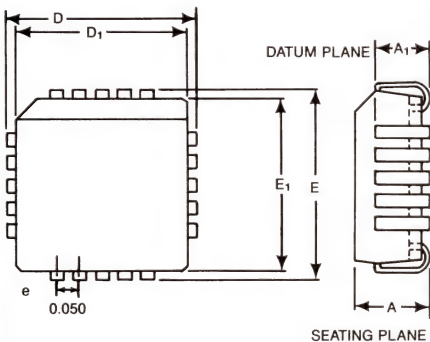


PACKAGE DIMENSIONS

SYMBOL	18 PINS		18 PINS		22 PINS		28 PINS		32 PINS	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
A	0.100	0.140	0.100	0.140	0.100	0.140	0.100	0.140	0.100	0.140
D	0.317	0.327	0.320	0.335	0.320	0.335	0.385	0.395	0.485	0.495
D <sub>1</sub>	0.282	0.288	0.287	0.293	0.283	0.293	0.347	0.353	0.447	0.453
E	0.457	0.467	0.520	0.535	0.520	0.535	0.585	0.595	0.585	0.595
E <sub>1</sub>	0.422	0.428	0.487	0.493	0.487	0.493	0.547	0.553	0.547	0.553

NOTE:  
ALL DIMENSIONS ARE GIVEN IN INCHES.

PLASTIC CHIP CARRIER (PCC), SQUARE

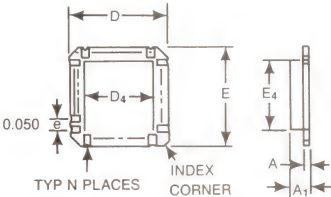


PACKAGE DIMENSIONS

SYMBOL	16 PINS		20 PINS		28 PINS		44 PINS		52 PINS		68 PINS		84 PINS		24 PINS	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
A	0.017	0.088	0.017	0.088	0.017	0.088	0.037	0.088	0.037	0.088	0.037	0.088	0.037	0.088	0.017	0.088
A <sub>1</sub>	0.064	0.100	0.064	0.100	0.064	0.100	0.069	0.120	0.082	0.120	0.082	0.120	0.082	0.120	0.064	0.100
D AND E	0.292	0.308	0.342	0.358	0.442	0.458	0.640	0.660	0.739	0.761	0.938	0.962	1.135	1.165	0.395	0.410
D <sub>1</sub> AND E <sub>1</sub>	0.257	0.308	0.307	0.358	0.406	0.458	0.495	0.560	0.495	0.560	0.495	0.862	0.495	1.065	0.352	0.408

NOTE:  
ALL DIMENSIONS ARE GIVEN IN INCHES.

LEADLESS CHIP CARRIER (LCC)



PACKAGE DIMENSIONS

SYMBOL	20 PINS		28 PINS		44 PINS		52 PINS		68 PINS		84 PINS		100 PINS		124 PINS	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
A	0.165	0.180	0.165	0.180	0.165	0.180	0.165	0.200	0.165	0.200	0.165	0.200	0.165	0.200	0.165	0.200
D AND E	0.385	0.395	0.485	0.495	0.685	0.695	0.785	0.795	0.985	0.995	1.185	1.195	1.385	1.395	1.685	1.695
D <sub>1</sub> AND E <sub>1</sub>	0.350	0.356	0.450	0.456	0.650	0.656	0.750	0.756	0.950	0.956	1.150	1.156	1.350	1.356	1.650	1.656

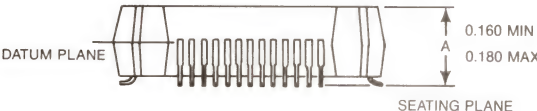
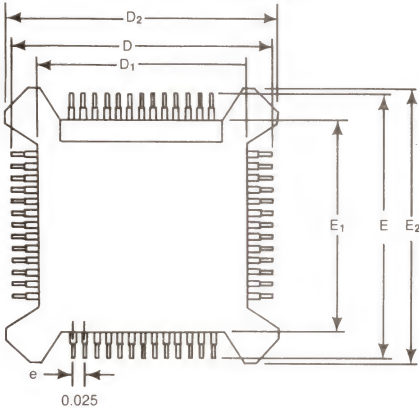
NOTE:  
ALL DIMENSIONS ARE GIVEN IN INCHES.

PACKAGE DIMENSIONS

SYMBOL	52 PINS		68 PINS		84 PINS		100 PINS		132 PINS		164 PINS		196 PINS		244 PINS	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
D AND E	0.575	0.585	0.675	0.685	0.775	0.785	0.875	0.885	1.075	1.085	1.275	1.285	1.475	1.485	1.775	1.785
D <sub>1</sub> AND E <sub>1</sub>	0.447	0.453	0.547	0.553	0.647	0.653	0.747	0.753	0.947	0.953	1.147	1.153	1.347	1.353	1.647	1.653
D <sub>2</sub> AND E <sub>2</sub>	0.597	0.603	0.697	0.703	0.797	0.803	0.897	0.903	1.097	1.103	1.297	1.303	1.497	1.503	1.797	1.803

NOTE:  
ALL DIMENSIONS ARE GIVEN IN INCHES.

PLASTIC QUAD FLAT PACK (PQFP)





## ADVERTORIAL

BOOTH #410

### *Multibus I Architecture Supports 32-Bit Transfers*

32-bit transfers across the Multibus<sup>®</sup>I Architecture with a 256Mbytes physical address space, (increased from 16Mbytes), and a 20Mbyte bandwidth within the IEEE 796 specification. "TRU-32" <sup>®</sup> defines the reserve lines in the P-2 backplane, giving a full 32-bit data width to all 23 slots in the Multibus I specification. As faster, more powerful CPU designs emerge, the costs for today's newer technology in open-architecture buses have sky-rocketed. Migration reluctance from embedded, well established buses is understandable when faced with the reality of: costly hardware changes, timely software learning curves, and off-the-shelf incompatibility among the new buses. This new scheme will benefit those who develop, design or manufacture around the best supported and well defined open-architecture in the world.

CIRCLE NO 129

### *80386 SBC Executes "Tru-32" Specifications*

The ZENDEX ZX-386 single-board computer incorporates the "TRU-32" specification with downward compatibility to all 16-bit and 8-bit Multibus I boards. A full function 32-bit SBC, the ZX-386 can be used in present Multibus I systems executing standard 16-bit data width or Zendex will make available the "P-32" backplane, (4 to 23 slots), supporting the TRU-32 specification for 32-bit applications. The board features a 16MHz 80386 processor; 80387 numeric coprocessor; 82380 DMA controller; 8Mbytes dual ported one wait state DRAM; 4 EPROM sockets; two serial ports; 4Mbyte per second SCSI interface; and two SBX connectors. "TRU-32 Development Kits" are available and include Interface scheme, PAL equations, and license for \$100.00. ZENDEX CORPORATION (415) 828-3000

CIRCLE NO 130

### *Intelligent Multibus I Extender Board*

A most useful tool to assist test technicians and engineers in trouble shooting Multibus I products has been designed and released by Zendex Corporation. The ZX-611 has sixteen LED's displaying buffered bus functions for 16-bit, 8-bit and the new 32-bit Multibus I specification. Two on board switches control: 1) systems reset and 2) local power for insertion and extraction of boards in extension without removing system power. Support arms relieve connector pressure and contact problems inherent to the weight of bus boards on extension. In addition, terminal pins for +5v and ground are mounted on the board for oscilloscope and probe attachment along with plated thru holes on P1 for user selective test points. ZENDEX CORPORATION (415) 828-3000

CIRCLE NO 131

### *Modular I/O Flexibility Through SBX*

As the ever increasing need for modular I/O intensifies a broad range of SBX Expansion Modules for the SBX specification have been developed. Expanding virtually any system with standard or custom designs, ZENDEX CORPORATION manufactures the largest selection of modules available. SCSI, Cmos SCSI, IEEE 488, HDLC, Modem, Servo controller, Stepper Motor controller, Encoder, Clock/Calendar, Disk controller, Dual Serial, A/D D/A Converter, and more. The ZENDEX ZX-564 mother board supports 6 SBX modules simultaneously, 8/16 bit transfers, 4 channels of DMA with user definable applications such as: Multiple Serial I/O, Industrial Control, Data Acquisition, and many more. ZENDEX CORPORATION (415) 828-3000

CIRCLE NO 132

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President  
SGS Semiconductor Corporation

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# High-Tech Take-Away

The portability and low price of our PM 3632 brings logic analysis within reach of every user in industry and education.

But not at any cost in performance.

Because this remarkable personal logic analyzer out-performs all other instruments in its class on the market!

Compare some of the benefits of this 'high-tech take-away' for yourself:

■ 100 MHz acquisition speed, or up to 32 channel data width cover demanding state/time applications in digital systems.

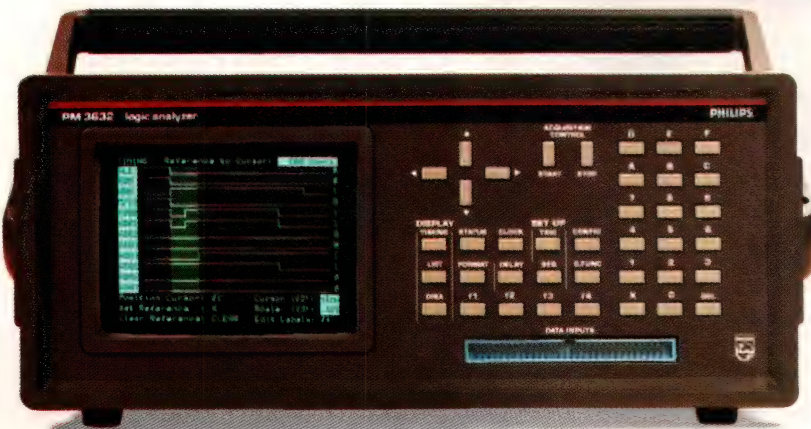
■ Wide ranging microprocessor support (incl. 68000/68010 and 8086/8087/8088 16-bit devices) and ROM emulation enhance operational versatility.

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**Test & Measurement**

# PHILIPS



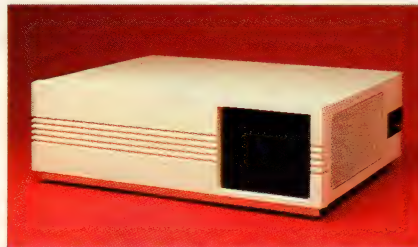


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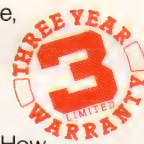


You do get a choice between two multiple-output power supplies: 190 Watts with 19A at +5V or 270 Watts with 30A at +5V. You can also choose a J2 backplane for VME extended addressing or iLBX II for a Multibus II system.

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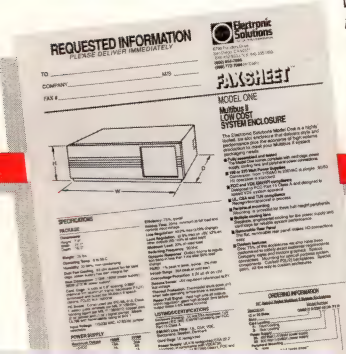


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CIRCLE NO 178

EDN February 18, 1988

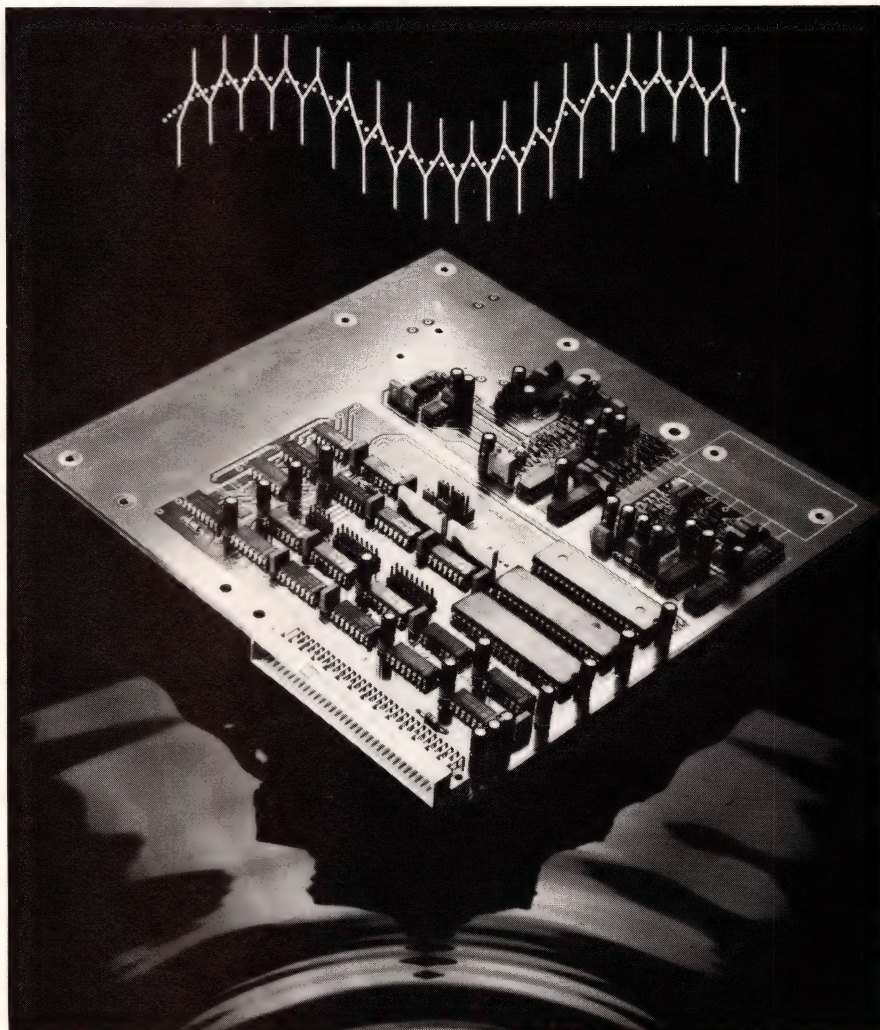


## Ripple-and-noise test module uses voltage-comparison technique

This ripple-and-noise test module, intended for use in testing switching-regulated power supplies, plugs into the vendor's 6500 modular automatic power-supply test system. The difficulty of reproducing switching-supply ripple-and-noise measurements has caused friction between power-supply vendors and their customers. The manufacturer claims to have solved that problem by replacing more conventional noise-measurement techniques with a method based on voltage-level and duty-factor sensing.

Peak-to-peak measurements of switching-supply noise are notoriously difficult to reproduce because of their extraordinary sensitivity to the bandwidth of the measurement instrumentation's peak-detection circuits. To overcome this problem and to pinpoint whether noise is associated with a supply's switching action or its conversion of line-frequency ac to dc, a common noise-measurement technique uses filters to separate switching-frequency noise from line-frequency-related ripple, and it uses an rms-to-dc converter to measure the filters' output. (A lowpass filter allows you to measure line-related noise components; a highpass filter passes the switching-frequency-related components.)

Because the supply's switching frequency is hundreds of times as high as the line frequency, it may seem as though you don't need filters with an especially sharp cutoff. However, only about  $5\frac{1}{2}$  octaves separate the seventh harmonic of the 60-Hz power line from the most common switching-regulator frequency, 20 kHz. If, for example, you use a single-pole lowpass filter to eliminate switching-frequency volt-



*This power-supply ripple-and-noise test module achieves improved measurement repeatability by using an unusual A/D-conversion technique in place of the more common filtering and rms-to-dc conversion methods.*

ages, you'll find that a filter that attenuates by only a little more than 33 dB (that is,  $<50\times$ ) at 20 kHz still produces a greater-than-desired 3 dB of attenuation of voltages at the seventh line-frequency harmonic.

If you attempt to improve the rejection of switching-frequency noise by lowering the filter's cutoff frequency, you further attenuate ripple components at harmonics of the line frequency. If, instead, you

increase the sharpness of the filter's cutoff characteristic, you can introduce peaks into the filter's passband response, which, even with careful selection of the cutoff frequency, may affect measurements of line-frequency-related ripple. At the very least, you'll probably find it tricky to design filters that yield measurements someone else can reproduce.

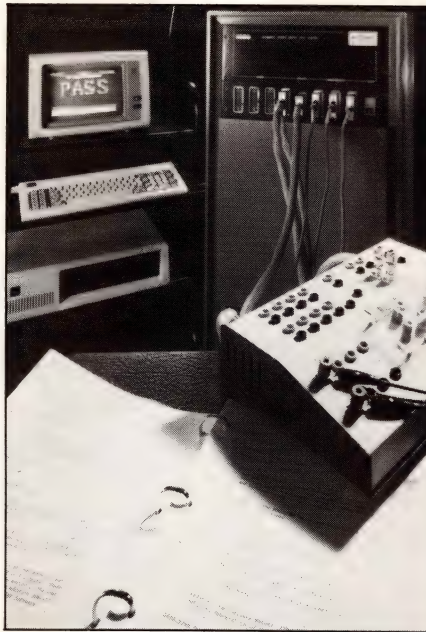
Although it appears that the



# PRODUCT UPDATE

trend toward higher switching-regulator operating frequencies will make it easier to obtain accurate ripple-and-noise measurements by using conventional techniques, remember that power-supply switching-noise waveforms contain a significant amount of energy at harmonics of the switching frequency higher than the 33rd. Slew-rate and bandwidth limitations in most rms-to-dc converters cause errors in measuring waveforms with such high-frequency components, and these errors worsen as the switching frequency increases.

The manufacturer's test module makes reproducible ripple-and-noise measurements by eliminating filters and rms-to-dc converters entirely. The module, which achieves a 30-MHz bandwidth, uses an unusual A/D-conversion technique and takes advantage of the fact that the switching-spike component of a power supply's ripple-and-noise



*You can configure the 6500 automatic power-supply test system in many ways. An IBM PC/XT or compatible computer is a popular controller. You can choose voltage sources, dynamic loads, and measurement modules of several types. A 16-slot backplane allows you to match system capabilities to your needs.*

waveform normally has a low duty factor. The module adjusts a voltage comparator's reference input signal until its value is less than the ripple and noise under examination for a programmable, and normally small, fraction of the total time. By adjusting the fraction until the reference-signal value begins to increase rapidly, you determine the noise-pulse duty factor. The module then reports the value of the reference signal—a value proportional to the ripple component of the ripple and noise. A 3-channel module costs \$3800; a 7-channel module sells for \$4500. Prices for the 6500 system range from \$30,000 to \$500,000; most configurations cost less than \$100,000.—**Dan Strassberg**

*Intepro Systems Inc, 450 Bedford St, Lexington, MA 02173. Phone (617) 863-9500. TLX 510-601-8053.*

**Circle No 720**

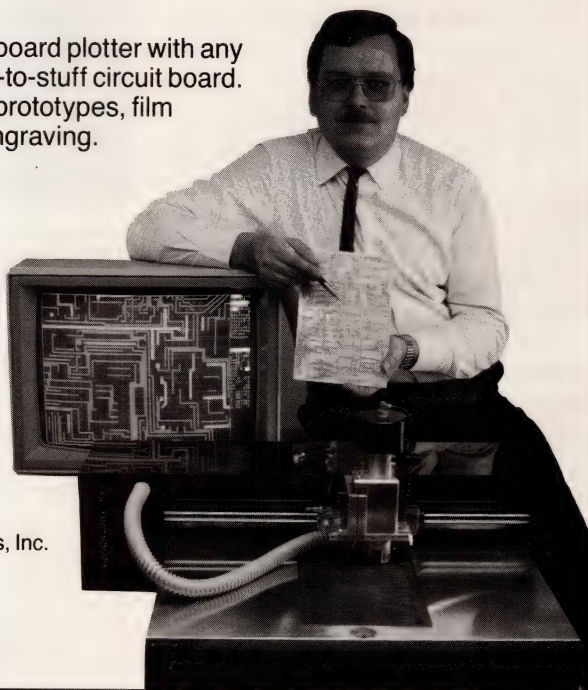
## From Layout to Finished Board ... In Minutes



Paths of insulation around copper traces are created by the precision router. The LPKF unit also performs drilling and contour milling to complete the circuit board production.

Now you can use the LPKF circuit board plotter with any Gerber CAD files to create a ready-to-stuff circuit board. This unique plotter is excellent for prototypes, film production, and even front-plate engraving.

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**CIRCLE NO 21**



Z I L O G



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Start with the most powerful 16-bit engine available, add on-board Cache, MMU and Burst Mode memory support — and you'll begin to understand the Z280's power and potential.

## ...powerful on-board peripherals...

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...and the glue to tie it all together.

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Programmable Wait State Logic — on board — you're really looking at significant glue reduction.

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	Z280™	80186	68070
Package	68-pin PLCC/CMOS	68-pin LCC/NMOS	84-pin PLCC/CHMOS
Typical Power	375 mW	2 W	800 mW (est)
Speed	10-25 MHz	8-12.5 MHz	10 MHz
Memory Support	16 Mb Physical Paged	1 Mb Physical Segmented	16 Mb Physical 8 or 128 Segments
16-bit Registers	12 General	8 General	15 Dedicated
Instruction Pre-fetch	256-Byte Assoc. Cache; Burst Mode	6-Byte Queue	None
Multiprocessor Support	Local or Global	Local only	Local only
Wait Logic	Programmable	Programmable	Hardwire
DMA	4 Channels, 6.6 Mb/s @ 10 MHz	2 Channels 2 Mb/s @ 8 MHz	2 Channels, 3.2 Mb/s @ 10 MHz
Counter/Timers	3 16-bit	3 16-bit	2 16-bit
Serial I/O	1 Full-Duplex UART	None	1 Full-Duplex UART
DRAM Controller	10-bit Refresh	None	None
Price (100)	\$33	\$43	\$50

## The choice is clear.

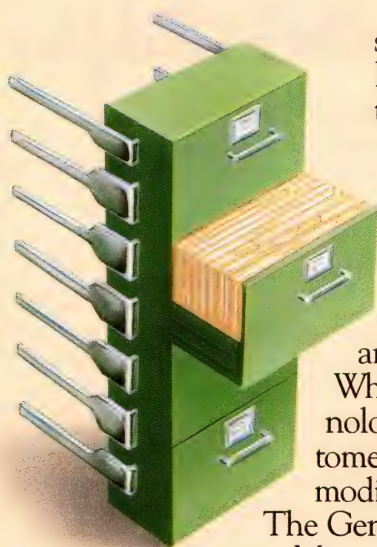
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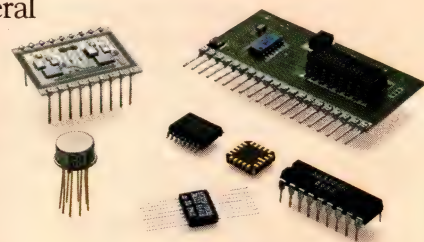
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# PRODUCT UPDATE

## Systems DMM lets you choose 8½-digit resolution or 100,000 readings/sec

Designed to be at home in a reference lab, on an engineer's bench, or in a test-equipment rack, the \$5900 Model 3458A digital multimeter offers a range of measurement speeds and resolutions that allow the instrument to tackle a wide variety of jobs. At its highest resolution, the DMM provides 8½-digit measurements; at its fastest speed, the multimeter takes 100,000 readings/sec. In addition, a precise timebase and a switchable, high-speed, track-and-hold input path allow the instrument to digitize repetitive waveforms to 15 MHz.

For situations requiring high-throughput measurement, the DMM can take 100,000 readings/sec with 4½ digits of resolution. The instrument's standard acquisition memory holds 10,000 readings, and a \$500 option adds storage capacity for an additional 64,000 readings. To allow for additional storage capacity or for data analysis, the multimeter can pump readings out through an IEEE-488 port to a computer at the full 100,000-reading/sec rate. The company supplies a \$1000 control-and-analysis software package for the DMM; the package runs on the vendor's Model 9000 workstations.

For applications that don't require the DMM's full measurement speed but that could make use of additional resolution, the instrument can take 50,000 5½-digit, 5000 6½-digit, or 60 7½-digit readings/sec. It performs 5 readings/sec when set to its maximum resolution of 8½ digits.

The instrument's internal input path incorporates an integrator with a 160-kHz bandwidth. You can digitize repetitive signals with frequencies to 15 MHz by switching the input path to a track-and-hold



*You can choose to take 100,000 4½-digit measurements/sec or five 8½-digit measurements/sec with the Model 3458A DMM.*

circuit and using the DMM's subsampling feature. The subsampling measurement technique takes a series of samples, one per cycle of the signal it's measuring. Following a trigger event that occurs once each cycle, the DMM waits longer (the increment is programmable) than it did during the previous cycle and then takes a sample. Over several cycles, the instrument builds a detailed picture of the signal's waveform. The DMM's sampling clock can operate at frequencies as high as 100 MHz, and it features less than 100 psec of jitter.

Automated test systems can readily use the DMM's flexible tradeoff between resolution and speed. The company claims that digital multimeters in automated test systems perform a large percentage of the measurements, so a faster DMM in such a test system will probably greatly improve overall system

throughput. In addition to the ability to take measurements quickly, the 3458A multimeter can perform as many as 200 function or range changes/sec and can take 250 auto-ranged measurements/sec.

To aid in making rapid range and function changes in a test environment, a program memory in the instrument stores measurement sequences that can be activated by the transfer of only a few bytes over the IEEE-488 interface. This program memory allows the DMM to make as many as 1000 limit checks/sec. You can calibrate the multimeter from its front panel (so it can remain in its system rack) with just two references—a 10-k $\Omega$  resistor and a 10V reference source—and a short circuit.

The company, which incorporated its proprietary multimeter language (HPML, also used in its earlier 3457A DMM) in the instrument, asserts that its future DMMs will also



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CIRCLE NO 22

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## UPDATE

support this language to ease future software changes. You can issue all of the HPML commands from the DMM's front panel as well as enter them through the instrument's IEEE-488 port.

The multimeter's accuracy specifications make it well suited for work in a reference laboratory. The company rates the instrument's dc-voltage accuracy at 0.5 ppm over 24 hours and 8 ppm over one year. An \$800 high-stability option improves that annual accuracy rating to 4 ppm. The linearity spec is 0.1 ppm over 24 hours and has been measured as being within 0.05 ppm of 10V against the Josephson-Junction Array voltage standard developed by the National Bureau of Standards in Boulder, CO. You can command the DMM to perform an automatic calibration against its internal reference standards, which have known drift and temperature coefficients.

Because the DMM can measure both ac and dc voltage and current, resistance, frequency, and period, it's likely to find a home on the test benches of engineers who need a high-precision, full-featured multimeter. Its dc-voltage measurements include five ranges from 0.1 to 1000V with a maximum sensitivity of 10 nV, and its resistance ranges can measure impedances from 10Ω to 1 GΩ (full scale) with 2-ppm accuracy. The ac-voltage scales, frequency counter, and period measurement accommodate signals with frequencies of 1 Hz to 10 MHz. The 3458A is available eight weeks ARO. A \$160 option extends the instrument's warranty period from one year to three years.

— **Steven H Leibson**

*Hewlett-Packard Co, 3495 Deer Creek Rd, Palo Alto, CA 94304.  
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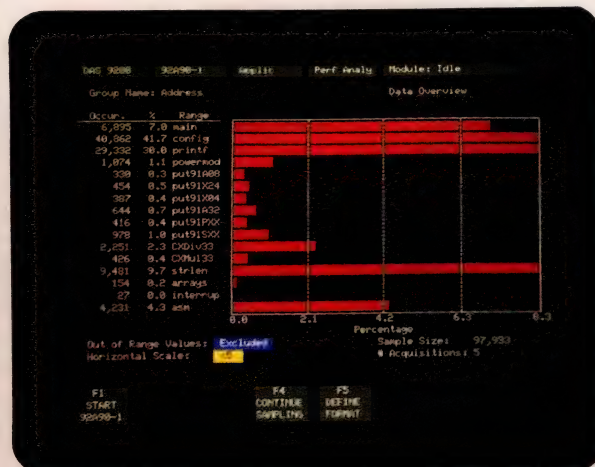
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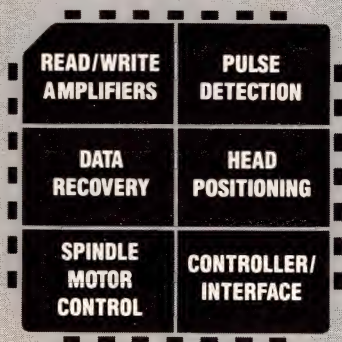
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## PRODUCT UPDATE

### Electrostatic plotters produce prints at 1 ips

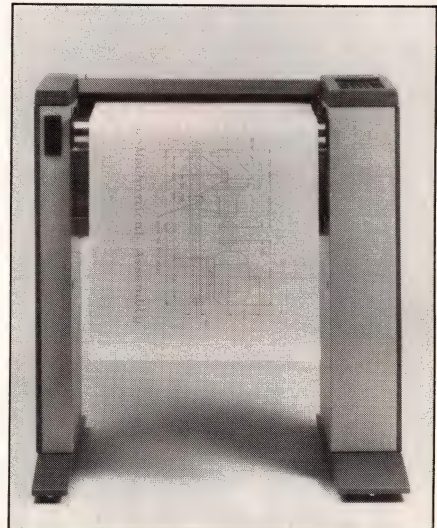
Electrostatic raster-printing technology gives the 8500 Series monochrome plotters a plotting speed of 1-ips. You can use the 24- and 36-in.-wide plotters as a department or network resource because of their fast output speed. Yet the devices are priced in the \$20,000 range, so they're affordable for use with a single workstation or personal computer.

Electrostatic plotters use a linear array of wire nibs to place images on the medium. The wire nibs selectively conduct an electrical charge that discharges dots on the dielectric surface of the coated medium. The medium then passes through a toner bath, and toner particles are fused to the selected charged dots forming the image. The wire nibs of the 8500 Series plotters produce a resolution of 200 dots/in.

Although electrostatic plotters are raster devices, the 8500 Series includes a controller that performs a vector-to-raster conversion. The controller accepts input in the HPGL (Hewlett-Packard Graphics Language) and Calcomp 906/907 vector data formats. The plotters include a Centronics parallel interface and an RS-232C serial interface that operates at speeds as high as 38.4k baud.

The plotters use roll-feed media, and they can produce more than 100 plots with a single roll. You can choose among various types of media, including opaque, translucent, and vellum paper and clear and matte polyester films. The plotters each include a manual cutter for the media. The company also offers an automatic cutter and a take-up roll for paper output; with either of these options, the plotters can operate unattended.

The Model 8524 plots on 24-in.-wide media and costs \$19,900, and



*HPGL and 906/907 vector data inputs drive the rasterizing controllers of the 8500 Series plotters, allowing the plotters to operate with most popular graphics-software packages.*

the Model 8536 uses 36-in.-wide media and sells for \$24,900. The 8536 can produce an E-size drawing in 45 sec, and either machine can plot a D-size drawing in 36 sec. The plot time does not vary with image complexity. However, the controller must rasterize a full graphics image before plotting begins.

The plotters can print multiple copies of an image at the 1 ips plotting speed. You simply select as many as 999 copies at the control panel. The control panel also allows you to choose a line thickness ranging from 3 to 90 mils. Further, it lets you scale or rotate a drawing, create a mirror image, and change a drawing's point of origin. Each plotter includes a floppy-disk drive that you can use to store and retrieve various plotter setups. The vendor offers OEM discounts on the plotters, and production quantities are available now.—**Maury Wright**

*Versatec, 2710 Walsh Ave, Santa Clara, CA 95051. Phone (408) 988-2800. TWX 910-338-0243.*

**Circle No 719**



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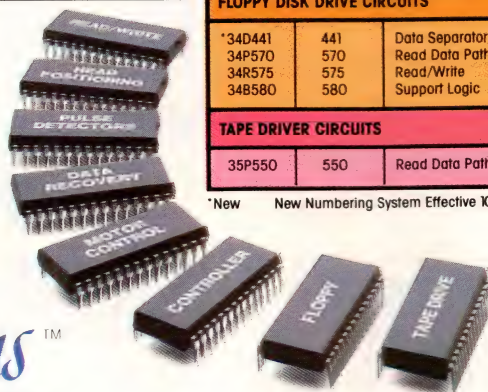
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## MICROPERIPHERAL IC SELECTION CHART

SSI Device Numbers		Head Type	# of Channels	Max Input Noise nV/√Hz	Max Input Capacitance (pF)	Read Gain (typ)	Write Current Range (mA)	Power Supplies	Read/Write Data Port(s)
New	Old								
HDD READ/ WRITE AMPLIFIERS									
32R104B	104	Ferrite	4	2.4	23	35	15 to 45	+6V, -4V	Differential, Bi-directional
32R104BLN	104L	Ferrite	4	1.7	23	35	15 to 45	+6V, -4V	Differential, Bi-directional
32R114	114	Thin Film	4	1.1	65	123	55 to 110	± 5V	Differential/Differential
32R115	115	Ferrite	2, 4, 5	1.8	20	40	30 to 50	± 5V	Differential, Bi-directional
32R117	117	Ferrite	2, 4, 6	2.1	23	100	10 to 50	+5V, +12V	Differential/TTL
32R117A	117A	Ferrite	2, 4, 6	1.7	20	100	10 to 50	+5V, +12V	Differential/TTL
32R188	188	Ferrite	4	2.4	18	43	35 to 70	+6V, -5V	Differential, Bi-directional
32R501	501	Ferrite	4, 6, 8	1.5	23	100	10 to 50	+5V, +12V	Differential/TTL
32R510A	510A	Ferrite	2, 4, 6	1.5	20	100	10 to 40	+5V, +12V	Differential/TTL
32R511	511	Ferrite	4, 6, 8	1.5	20	100	10 to 40	+5V, +12V	Differential/TTL
32R512	512	Thin Film	8	0.9	32	150	10 to 40	+5V, +12V	Differential/TTL
32R514	514	Ferrite	2, 4, 6	1.5	20	150	10 to 40	+5V, +12V	Differential/TTL
32R520	520	Thin Film	4	0.9	65	123	30 to 75	± 5V	Differential/Differential
32R521	521	Thin Film	6	0.9	65	100	20 to 70	+5V, +12V	Differential/TTL
32R522	522	Thin Film	4, 6	1.0	32	100	6 to 35	+5V, +12V	Differential/TTL

SSI Device Numbers		Circuit Function	Features
New	Old		
HDD PULSE DETECTION			
32P540 32P541	540 541	Read Data Processor Read Data Processor	Time Domain Filter AGC, Amplitude & Time Pulse Qualification, RLL Compatible
HDD DATA RECOVERY			
32D531 *32D532 *32D533 *32D534 *32D535	531 532 533 534 535	Data Synchronizer Data Separator Data Synchronizer Data Separator Data Separator	Data Synchronizer/Write Precompensation Data Synchronizer/2, 7 RLL ENDEC Data Synchronizer/Write Precompensation Data Synchronizer/MFM ENDEC/Write Precompensation Data Synchronizer/2, 7 RLL ENDEC/Write Precompensation
HDD HEAD POSITIONING			
32H101A 32H116 *32H567 *32H568 *32H569	101A 116 567 568 569	Preamplifier-Ferrite Head Preamplifier-Thin Film Head Servo Demodulator Servo Controller Servo Motor Driver	AV = 93, BW = 10MHZ, $e_n = 7.0nV/\sqrt{Hz}$ AV = 250, BW = 20MHZ, $e_n = 0.94nV/\sqrt{Hz}$ Di-bit Quadrature Servo Pattern; PLL Synchronization Track & Seek Mode Operation; Microprocessor Interface Head Parking, Spindle Motor Braking
HDD SPINDLE MOTOR CONTROL			
32M590 32M591 *32M593	590 591 593	2-Phase Motor Speed Control 3-Phase Motor Speed Control 3-Phase Motor Speed Control	$\pm 0.035\%$ Speed Accuracy; Unipolar Operation $\pm 0.05\%$ Speed Accuracy; Unipolar Operation $\pm 0.037\%$ Speed Accuracy; Bipolar Operation
HDD CONTROLLER/INTERFACE			
*32B450A *32C452 *32C453 32B545	450A 452 453 545	SCSI Controller Storage Controller Buffer Controller Support Logic	Async transfer to 2MBPS; Initiate/Target Modes; Internal Drivers; CMOS 20Mbits/sec; CMOS; Programmable; AIC-010 Compatible Non-mux addressing to 16K; CMOS; AIC-300 Compatible Includes ST506 Bus Drivers/Receivers
FLOPPY DISK DRIVE CIRCUITS			
*34D441 34P570 34R575 34B580	441 570 575 580	Data Separator Read Data Path Read/Write Support Logic	High Performance Analog Data Separator, NEC 765 Compatible 2 Channel Read/Write With Read Data Path 2, 4 Channel Read/Write Circuit Port Expander, Includes SA400 Interface Drivers/Receivers
TAPE DRIVER CIRCUITS			
35P550	550	Read Data Path	4 Channel Read/Write With Read Data Path

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## Monolithic A/D converter delivers 1-MHz, 12-bit performance at low cost

For designs that require a high-speed, 12-bit sampling A/D converter, consider using the CSZ5412-JC1, a monolithic 1-MHz A/D converter. This IC offers speed and accuracy that matches or exceeds the performance of hybrid alternatives while consuming a third of the power—700 mW—and selling for only \$180 (100). This price includes the sample-and-hold circuitry that you must add to many competing hybrid devices.

Using a 2-step flash A/D conversion to achieve its high speed and accuracy, the CSZ5412 incorporates self-calibrating circuitry, pipelined acquisition and settling times, and overlapped conversion cycles. The 2-step technique requires a track-and-hold amplifier, a 6-bit flash A/D converter, a 6-bit D/A converter, and a differential amplifier—all of which are provided on the chip's

monolithic substrate.

The device's pipelined settling times, which are used in both the sampling and the conversion processes, give the converter its 1-MHz throughput rate. The device can actually begin a conversion cycle while it's still operating on the previous sample. This process of overlapping the conversion cycles by using a pair of track-and-hold amplifiers results in a throughput time that's shorter than the device's conversion time.

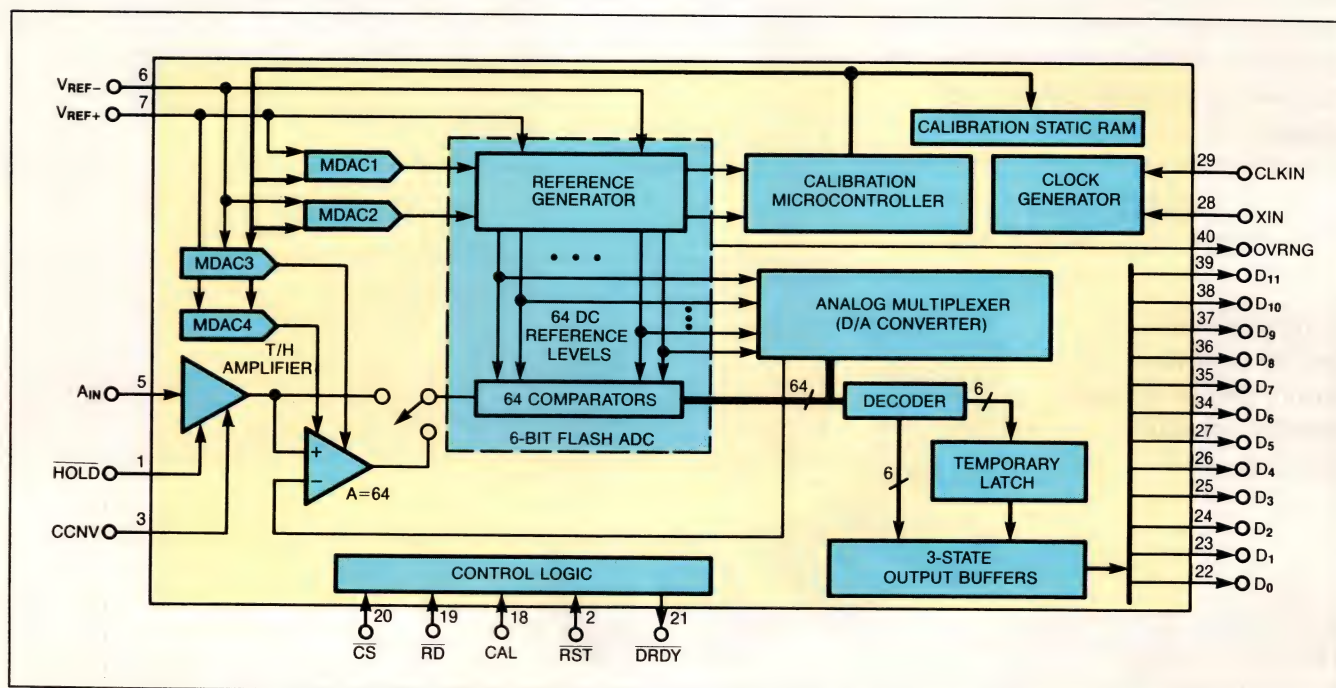
The CSZ5412 uses several calibration techniques to ensure 12-bit accuracy over time and temperature. For example, it has a reference-generating circuit that provides 64 graduated reference levels; the circuit continually adjusts the levels to 12-bit accuracy. Further, an on-chip  $\mu$ C provides digital correction that calibrates the device's gain and offset and minimizes linearity errors at

the 64 segment boundaries.

You can connect the converter directly to a  $\mu$ P's data and control buses because it comes with an over-range output, 3-state output buffers, and a flexible control interface. Alternatively, the device can operate in stand-alone mode, independently of microprocessor control. The converter specs a 3V analog-input range. The device's total harmonic-distortion spec is 0.02%, and its dynamic range is 72 dB. You can also order a similar device, the CSZ5412-JC2, which has a 500-kHz conversion rate and costs \$115 (100).—**J D Mosley**

*Crystal Semiconductor Corp, Box 17847, Austin, TX 78760. Phone (512) 445-7222. TWX 910-874-1352.*

**Circle No 721**



**This 40-pin monolithic CMOS A/D converter** is a low-power, low-cost, self-calibrating device that provides a 12-bit representation of an analog input signal at sampling rates as fast as 1 MHz.



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CIRCLE NO 176



### Rack-mountable, 5½-digit programmable multimeter features 8-channel scanner

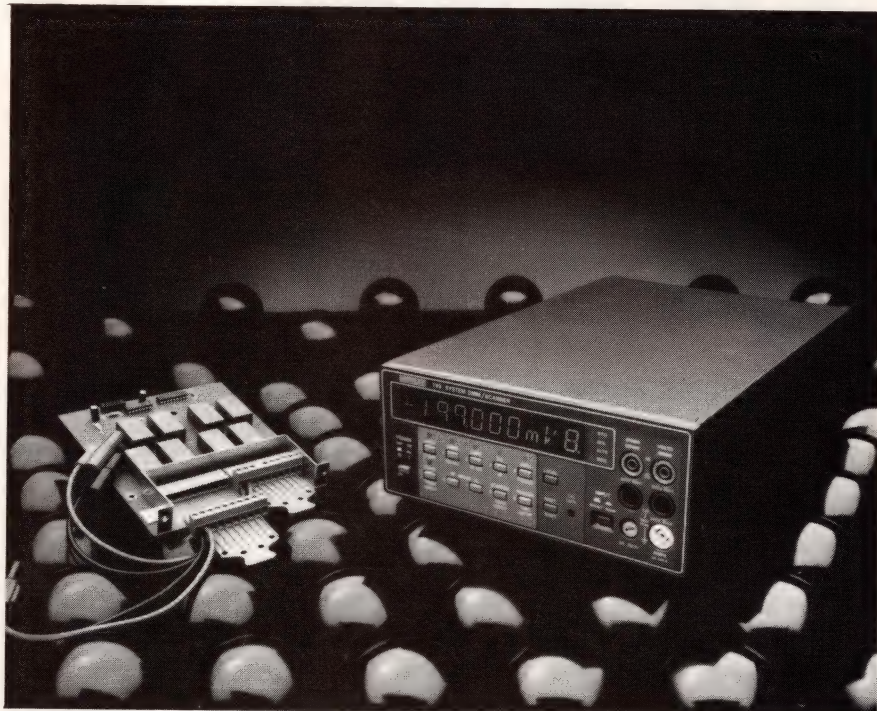
Combining two instruments in one half-rack-size enclosure, the Model 199 systems digital multimeter and scanner is a \$1395 instrument that provides \$3000 of functionality: Purchased separately, the devices would cost \$3000. You can order the Model 199 without its scanner option for \$995—a price lower than that of most other 5½-digital multimeters on the market.

The multimeter's mainframe features microprocessor control, which allows the instrument to control a switching module. The multimeter alone measures dc and ac voltage, dc and ac amps, ohms, and decibels. By adding the 8-channel scanner option, you transform the instrument into a complete multichannel measurement system.

The instrument's sensitivity specs are 1  $\mu$ V, 1 m $\Omega$ , and 100 nA, and its best 1-year dc-voltage accuracy is 0.007% of reading. You can take 150 readings/sec at a resolution of 4½ digits and store them in an internal buffer. You can trigger the readings externally.

The optional scanner, which you can install at your site, offers a switching speed of 400 channels/sec (including measurement time), 2-pole and 4-pole switching, and less than 1- $\mu$ V thermal offset in switch contacts. The low thermal offset lets the Model 199 accurately switch and measure low signal levels. Further, the scanner's 4-pole switching mode provides Kelvin-type (4-wire) resistance measurements.

The unit can switch and take measurements across 40 channels/sec. The manufacturer specifies a 25-msec internal delay between channel changes; this delay includes switch settling time as well as the



*Combining an IEEE-488 digital multimeter and an 8-channel scanner in a single enclosure, the Model 199 offers 5½-digit precision and costs \$1395. Its Translator software lets you easily convert the code of your existing test programs for use on the 199.*

time it takes to process a reading.

The multimeter, which you can program via its IEEE-488 bus, houses 500 memory locations. By using internal memory to store readings, the unit can reach its maximum speed of 150 readings/sec.

By adding the scanner, you can use the Model 199 as an 8-channel data logger that operates either under computer control or as a stand-alone instrument. The data logger can take readings at intervals varying from 16 msec to 16.6 minutes, or it can take readings asynchronously, at the command of external control equipment. With the scanner, the multimeter can also subtract, divide, and compute the ratio of two values.

The multimeter comes with

Translator, a program that lets you add the Model 199 to your existing automated-test system, yet make only minimal changes to any test software you've already written. Translator replaces lengthy IEEE-488 device-dependent program code with short, mnemonic commands. It allows the multimeter to execute a program written for another multimeter or scanner when you place special translation statements at the beginning of your test program. The Translator software codes reside in the DMM's nonvolatile memory.

—J D Mosley

Keithley Instruments Inc, 28775  
Aurora Rd, Cleveland, OH 44139.  
Phone (216) 248-0400. TLX 985469.

Circle No 722



KEITHLEY 199 SYSTEM DMM/SCANNER

STO  
HOL  
FLTR  
REM

CHMS  
TENSE  
PA  
100V MAX  
100V MAX

VOLTS  
CHMS

POWER  
OFF ON  
0 1

VOLT  
OHMS  
AMPS  
PA  
ZERO  
LOCAL

STING  
HCALL  
FLTR  
W  
RESHA

AUTO  
RANGE  
SCANNER  
TRIGGER

CHMS  
STEP  
SCAN  
TIME  
SETUP

INPUT  
CAL  
LOCK  
NEXT  
UNIT

FRONT REAR  
LO  
100V MAX  
100V MAX

1A 250V  
1A 100V

# Over Achiever:

WARNING: ⚠ USER SUPPLIED LETHAL VOLTAGE PRESENT ON SCANNER CONNECTORS. NO INTERNAL OPERATOR SERVICEABLE PARTS. SERVICE BY QUALIFIED PERSONNEL ONLY. DISCONNECT LINE CORD, INPUTS AND OUTPUTS BEFORE SERVICING. FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE FUSE WITH SAME TYPE AND RATING.

EXT TRIGGER INPUT METER COMPLETE OUTPUT

LINE VOLTAGE SELECTED

LINE FUSE SLOW BLOW

IEEE 488 INTERFACE

30V MAX

90-110V 180-220V

3/16A 90-125V 105-125V 210-250V

1/10A 180-250V 20VA MAX 50-60Hz AC

MADE IN U.S.A.

**KEITHLEY**



# Put a complete DMM in your measurement system.

Satisfy your measurement needs with the

Model 199's 5½-digit resolution and 6-function performance: DC and AC volts, , DC and AC amps, ohms (2- and 4-wire), and dB (for AC volts and amps). All standard—and so is the IEEE-488 interface.

You also get excellent Keithley sensitivity (1μV, 1mΩ, 100nA), with 60ppm accuracy\*. And the 199 gives you the extras, like a 500-reading internal memory, to help get the most from your most essential measurement instrument. Use the 199 on your bench or in a system—it's cost-effective and convenient in both situations.

\*DC volts, 90 days.

**Fast—Where It Counts.** The Model 199 isn't just fast, it's fast where it counts—in your high performance test system. You can synchronize the 199 to your system and achieve a rate of 150 readings per second, with 4½-digit resolution. Storing readings in the 500-point memory frees your system controller for other work.

## Stand-Alone Data

**Logging.** Use the Model 199 to track drift or other trends. Under front panel control, the 199 can be programmed to automatically store up to 500 readings at intervals from 15ms to 16.6 minutes (over 5 days of data), or at any externally-triggered time interval.

## More Performance, Maximum Utility.

- Enable a 30-reading running average filter to measure noisy signals.
- Use the ZERO function to subtract offsets or make measurements referenced to a user-defined baseline
- Display messages to prompt an operator in a semi-automated system.
- Save your DMM setup to avoid reprogramming the Model 199 on power-up.
- Automatically calibrate the Model 199 from the IEEE-488 bus on either front or rear inputs. Seal the front panel calibration lock switch for security.
- Reduce programming time—use the 199's non-volatile TRANSLATOR software to reduce the length of transmitted command strings, or to emulate the commands of an older DMM.





## DC VOLTS (5½ Digits)

RANGE	RESOLUTION	INPUT RESISTANCE	ACCURACY <sup>1</sup> ±(%rdg + counts)		
			24 Hours <sup>2</sup>	90 Days	1 Year
			23° ±1°C	18°-28°C	18°-28°C
300 mV	1 µV	>1 GΩ	0.004 + 3 <sup>3</sup>	0.009 + 3 <sup>3</sup>	0.012 + 3 <sup>3</sup>
3 V	10 µV	>1 GΩ	0.003 + 2	0.006 + 2	0.007 + 2
30 V	100 µV	11 MΩ	0.004 + 2	0.008 + 2	0.009 + 2
300 V	1 mV	10 MΩ	0.004 + 2	0.008 + 2	0.009 + 2

<sup>1</sup>For 4½-digit accuracy, count error is 5 (except 15 on 300mV range).

<sup>2</sup>Relative to calibration standards.

<sup>3</sup>When properly zeroed.

**CMRR:** >120dB at dc, 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

**NMR:** >60dB at 50Hz or 60Hz (±0.05%).

**MAXIMUM ALLOWABLE INPUT:** 300V rms or 425V peak, whichever is less.

## OHMS (5½ Digits)

RANGE	RESOLUTION	NOMINAL I-SHORT	ACCURACY <sup>1</sup> ±(%rdg + counts)		
			24 Hours <sup>4</sup>	90 Days	1 Year
			23° ±1°C	18°-28°C	18°-28°C
300 Ω	1 mΩ	1.7 mA	0.005 + 4 <sup>3</sup>	0.009 + 4 <sup>3</sup>	0.012 + 4 <sup>3</sup>
3 kΩ	10 mΩ	1.7 mA	0.004 + 2	0.008 + 3	0.009 + 3
30 kΩ	100 mΩ	160 µA	0.004 + 2	0.008 + 3	0.009 + 3
300 kΩ	1 Ω	50 µA	0.014 + 2	0.024 + 3	0.026 + 3
3 MΩ	10 Ω	5 µA	0.02 + 2	0.03 + 3	0.03 + 3
30 MΩ	100 Ω	0.5 µA	0.1 + 5	0.12 + 5	0.12 + 5
300 MΩ	1 kΩ	0.5 µA	2.0 + 5	2.0 + 5	2.0 + 5

<sup>1</sup>For 4½-digit accuracy, count error is 5 (except 15 on 300Ω range).

<sup>2</sup>4-wire accuracy, 300Ω-30kΩ ranges.

<sup>3</sup>When properly zeroed.

<sup>4</sup>Relative to calibration standards.

**CONFIGURATION:** Automatic 2- or 4-wire.

**MAXIMUM ALLOWABLE INPUT:** 300V rms or 425V peak, whichever is less.

**OPEN CIRCUIT VOLTAGE:** <5.5V.

## TRMS AC VOLTS (5½ Digits)

RANGE	RESOLUTION	ACCURACY <sup>1</sup> ±(%rdg + counts) 1 Year, 18°-28°C			
		20 Hz	50 Hz	200 Hz	20 kHz
		-50 Hz <sup>2</sup>	-200 Hz <sup>2</sup>	-20 kHz <sup>2</sup>	-100 kHz <sup>3</sup>
300 mV	1 µV	2 + 100	0.35 + 100	0.15 + 200	2.0 + 300
3 V	10 µV	2 + 100	0.35 + 100	0.15 + 200	1.5 + 300
30 V	100 µV	2 + 100	0.35 + 100	0.15 + 200	1.5 + 300
300 V	1 mV	2 + 100	0.35 + 100	0.15 + 200	1.5 + 300

<sup>1</sup>For 4½-digit accuracy, divide count error by 10; 4½-digit specifications apply for inputs >200Hz.

<sup>2</sup>Sinewave inputs >2000 counts.

<sup>3</sup>Sinewave inputs >20,000 counts.

**RESPONSE:** True root mean square, ac coupled.

**CREST FACTOR (ratio of peak to rms):** Up to 3:1 allowable.

**NON-SINUSOIDAL INPUTS (>20,000 counts):**

For rectified sine wave, add 0.3% of reading to above specifications for fundamental frequencies <20kHz.

For pulse waveforms, add 0.3% of reading for fundamental frequencies <1kHz, or 3.5% for frequencies <10kHz.

**INPUT IMPEDANCE:** 1MΩ shunted by <100pF.

**MAXIMUM ALLOWABLE INPUT:** 300V rms or 425V peak, 10<sup>7</sup>V•Hz, whichever is less.

**CMRR:** >60dB at 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

**SETTLING TIME:** 1 second to within 0.1% of change in reading.

**dB (ref = 1V):**

INPUT	RESOLUTION	ACCURACY ± dB 1 Year, 18°-28°C	
		20 Hz-20 kHz	20 kHz-100 kHz
-34 to +49 dB (20 mV to 300 V)	0.01 dB	0.2	0.4
-54 to -34 dB (2 mV to 20 mV)	0.01 dB	1.1	—

## DC AMPS (5½ Digits)

RANGE	RESOLUTION	ACCURACY <sup>1</sup> ±(%rdg + counts)	MAXIMUM VOLTAGE BURDEN
		1 Year, 18°-28°C	
30 mA	100 nA	0.05 + 15	0.4 V
3 A	10 µA	0.1 + 15	2 V

<sup>1</sup>For 4½-digit accuracy, count error is 20.

**MAXIMUM ALLOWABLE INPUT:** 3A. Protected with 3A, 250V fuse accessible from front panel.

## TRMS AC AMPS (5½ Digits)

RANGE	RESOLUTION	ACCURACY <sup>1</sup> ± (%rdg + counts) 1 Year, 18°-28°C		MAXIMUM VOLTAGE BURDEN
		20 Hz-45 Hz	45 Hz-10 kHz	
30 mA	100 nA	2 + 100	0.6 + 100	0.4 V
3 A	10 µA	2 + 100	0.6 + 100	2 V

<sup>1</sup>Inputs >2000 counts. For 4½-digit accuracy, divide count error by 10; 4½-digit specifications apply for inputs >200Hz.

**RESPONSE:** True root mean square, ac coupled.

**CREST FACTOR (ratio of peak to rms):** Up to 3:1 allowable at ⅓ full range.

**NON-SINUSOIDAL INPUTS:** Specified accuracy for fundamental frequencies <1kHz.

**MAXIMUM ALLOWABLE INPUT:** 3A. Protected with 3A, 250V fuse accessible from front panel.

**SETTLING TIME:** 1 second to within 0.1% of final reading.

**dB (ref = 1mA):**

INPUT	RESOLUTION	ACCURACY ± dB 1 Year, 18°-28°C	
		20 Hz-10 kHz	
-14 to +69 dB (200 µA to 3 A)	0.01 dB	0.6	



**MAXIMUM READING RATES (Readings/Second)<sup>1</sup>****DCV, DCA, ACV, ACA**

RESOLUTION	Continuous Into Memory MUX:		External Trigger Into Memory MUX:		Triggered Via IEEE-488 Bus <sup>2</sup> MUX:	
	OFF	ON	OFF	ON	OFF	ON
4½-Digit	65	65	150	62	80	49
5½-Digit	35 (29)	9 (7.5)	40 (33)	9 (7.5)	34 (29)	9 (7.5)

**OHMS**

RESOLUTION	Continuous Into Memory MUX:		External Trigger Into Memory MUX:		Triggered Via IEEE-488 Bus <sup>2</sup> MUX:	
	OFF	ON	OFF	ON	OFF	ON
4½-Digit	43	20	47	20	30	18
5½-Digit	16 (13)	9 (7.5)	18 (15)	9 (7.5)	15 (12.5)	9 (7.5)

<sup>1</sup>Reading rates are for fixed range readings with filters off, for 3V, 3k $\Omega$ , and 30mA ranges. 5½-digit rate is for 60Hz operation. Values in parentheses are for 50Hz operation.

<sup>2</sup>One shot on TALK.

**STORAGE & SCANNING CAPABILITIES**

**500-Reading Memory:** Stores reading, range, and scanner channel.

**Trigger:** One shot or continuous from front panel, IEEE-488 bus, and rear panel BNC.

**Programmable Reading Interval:** 15ms to 999.999s.

**Programmable Trigger Delay:** 1ms to 999.999s.

**WITH MODEL 1992 8-CHANNEL SCANNER**

**Programmable Configuration:** 2- or 4-pole.

**Programmable Channel Limit:** 1 to 8.

**Programmable Scanning Modes:** Manual, step, and scan.

**Ratio:** Channels 2 through 8 referenced to Channel 1.

**IEEE-488 BUS IMPLEMENTATION**

**MULTILINE COMMANDS:** DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

**UNILINE COMMANDS:** IFC, REN, EOI, SRQ, ATN.

**INTERFACE FUNCTIONS:** SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

All front panel functions and programs are available over the IEEE-488 bus, in addition to Status, Service Request, Output Format, EOI, Trigger, Terminator, Display Message, and Non-Volatile TRANSLATOR.

IEEE-488 address is programmable from the front panel.

**MODEL 1992 SCANNER OPTION**

**CONTACT CONFIGURATION:** 8-channel 2-pole, or 4-channel 4-pole.

**CONTACT POTENTIAL:** <1 $\mu$ V per contact pair.

**MAXIMUM SWITCHING RATE:** 40 channels/second, including Model 199 4½-digit DCV reading time.

**CONNECTOR TYPE:** Quick disconnect screw terminals, #14 AWG maximum wire size.

**MAXIMUM SIGNAL LEVEL:** 200V peak, 100mA, resistive load.

**CONTACT LIFE:** >10<sup>6</sup> operations (at maximum signal level); >10<sup>8</sup> operations (cold switching).

**CONTACT RESISTANCE:** <1 $\Omega$ .

**ISOLATION BETWEEN ANY TWO TERMINALS:** >10<sup>9</sup> $\Omega$ , <75pF.

**ISOLATION BETWEEN ANY TERMINAL AND EARTH:** >10<sup>9</sup> $\Omega$ , <150pF.

**COMMON MODE VOLTAGE:** 350V peak between any terminal and earth.

**MAXIMUM VOLTAGE**

**BETWEEN ANY TWO TERMINALS:** 200V peak.

**MAXIMUM VOLTAGE BETWEEN ANY TERMINAL AND MODEL 199 INPUT LO:** 200V peak.

**DIMENSIONS, WEIGHT:** 25mm high  $\times$  130mm wide  $\times$  170mm deep (1 in.  $\times$  5 in.  $\times$  6½ in.). Adds 0.3kg (8 oz.) to Model 199.

**GENERAL**

**MAXIMUM READING:** 302,999 counts in 5½-digit mode.

**CONNECTORS:** **Measurement:** Switch selectable front or rear, safety jacks. **Digital:** TRIGGER input and METER COMPLETE output on rear panel, BNCs.

**WARMUP:** 2 hours to rated accuracy.

**TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C):** < $\pm$ (0.1  $\times$  applicable accuracy specification)/°C.

**ISOLATION:** Input LO to IEEE LO or power line ground: 500V peak. 5  $\times$  10<sup>5</sup> V $\cdot$ Hz maximum. >10<sup>9</sup> $\Omega$  paralleled by 400pF.

**OPERATING ENVIRONMENT:** 0°-50°C, 80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°-50°C (0%-60% RH up to 28°C on 300M $\Omega$  range).

**STORAGE ENVIRONMENT:** -25° to +65°C.

**POWER:** 105-125V or 210-250V, rear panel switch selected, 50Hz or 60Hz, 20VA maximum. 90-110V and 180-220V versions available upon request.

**DIMENSIONS, WEIGHT:** 90mm high  $\times$  220mm wide  $\times$  330mm deep (3½ in.  $\times$  8¾ in.  $\times$  12¾ in.). Net weight 3kg (6 lbs., 8 oz.).

**ACCESSORIES SUPPLIED:** Model 1751 Safety Test Leads, Instruction Manual.

**ACCESSORIES AVAILABLE:**

Model 1992: 8-Channel Scanner

Model 1993: Quick Disconnect Scanner Connector Kit

Model 1998-1: Single Fixed Rack Mounting Kit

Model 1998-2: Dual Fixed Rack Mounting Kit

Model 1651: 50-Ampere Shunt

Model 1681: Clip-On Test Lead Set

Model 1682A: RF Probe

Model 1685: Clamp-On Current Probe

Model 1751: General Purpose Test Leads

Model 1754: Universal Test Lead Kit

Model 5806: Kelvin Clip Leads

Model 7007-1: Shielded IEEE-488 Cable, 1m

Model 7007-2: Shielded IEEE-488 Cable, 2m

Model 7008-3: IEEE-488 Cable, 0.9m (3 ft.)

Model 7008-6: IEEE-488 Cable, 1.8m (6 ft.)



Add the 1992 Scanner option to make the 199 an integrated, 8-channel measurement system.

The Model 199 DMM/Scanner combination can switch and measure up to 40 channels per second. And the sensitivity of the 199 is accessible through the scanner—each set of contacts creates less than  $1\mu\text{V}$  contact error. You can also make low level resistance measurements—the scanner

$$\text{Ratio} = \frac{\text{Channel } n}{\text{Channel } 1}$$

( $n = 2, \dots, 8$ )

can make 4-wire measurements on 4 channels or 2-pole measurements on 8 channels. Directly display Ratio for testing components to specific tolerances.

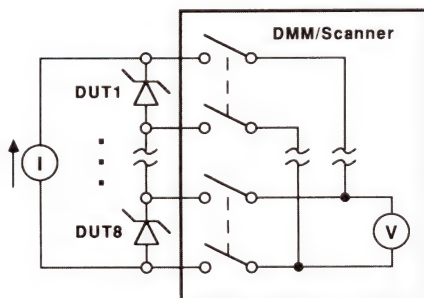


Use the Model 199 DMM/Scanner to evaluate multiple components, such as zener diodes, in a single test. Use the scanner in three different ways:

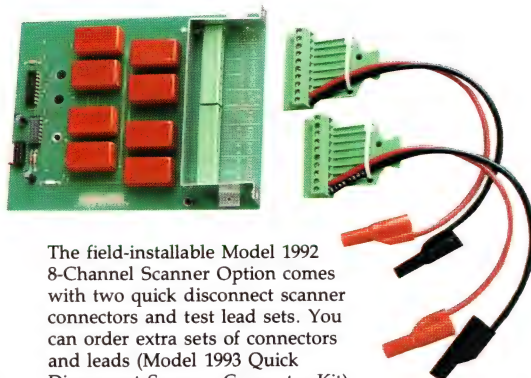
**Manual:** Operate channels individually.

**Step:** Automatically increment through each channel at a defined interval.

**Scan:** Automatically scan a set of channels at a defined interval.



# Put a complete measurement system in your DMM.



The field-installable Model 1992 8-Channel Scanner Option comes with two quick disconnect scanner connectors and test lead sets. You can order extra sets of connectors and leads (Model 1993 Quick Disconnect Scanner Connector Kit) to save different wiring setups.

## Savings Through Integration

By combining two instruments in one, Keithley saves you:

- **Valuable rack space:** The 199 comes in a new, compact package.
- **Learning time:** Start up quickly by learning one instrument instead of two.
- **Controller time:** Reduced IEEE-488 bus handshake time.
- **One IEEE-488 address.** Access a single location.
- **Cost:** Use the Model 199 DMM/Scanner instead of up to 8 DMMs, a DMM and separate scanner, or an 8-channel datalogger.

## Complete Confidence For Your Complete System.

Keithley recognizes your need for incorporating reliable instrumentation into your system. The high-reliability design and 2-year warranty of the Model 199 DMM/Scanner make it an excellent value.



# Model 196: Extended system performance.

When even smaller changes must be measured, the 6½-digit Model 196 System DMM provides the necessary extended performance. The 196 resolves changes as small as **1 part in 3,000,000**, and with excellent sensitivity. You can make these measurements with confidence: the 196 is accurate to **30ppm** (DC volts, 90 days). In addition, **offset**

**compensated ohms** eliminates errors caused by thermal contact potentials.

When high speed is your main concern, the Model 196 can take 3½-digit readings at **1000 per second** into its 500-reading memory.

With front/rear inputs, Voltmeter Complete and External Trigger signals, and IEEE-488 interface, the Model 196 provides **full-rack systems capability**—in a half rack case, at a half rack price.



	Sensitivity	Maximum Reading	Basic Accuracy
DCV	100nV	300V	0.003%
ACV	1μV	300V	0.15%
Ohms	100μΩ	300MΩ	0.005%
DCA, ACA	1nA	3A	0.05% 0.6%

## FRONT PANEL PROGRAMS

Menu	Set Hi/Lo Limits
Display Resolution	Digital Calibration
mX+b	Reset to factory default conditions
Hi/Lo/Pass	Offset Compensation
Multiplex On/Off	Save Setup
IEEE-488 Address	Zero Modify
Line Frequency	Filter Constants
Self Test	dB Reference
Set m,B Constants	

## Complete Support For Your Application.

Our full line of precision sources, scanners, and measurement instruments enables you to build a complete system of compatible Keithley components for your application. Incorporate powerful software packages such as ASYST and DADiSP to handle your data acquisition and analysis needs.



SOURCE • MEASURE • CONNECT

Our Application Engineers are available to discuss your difficult measurement requirements with you. We do more than just tell you how to operate our instruments—we offer suggestions to help you solve your measurement problems. Contact our Information Center to discuss your requirements with an Application Specialist.

# KEITHLEY

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 ITALY: Keithley Instruments SRL / Viale S. Gimignano 4/A / 20146 Milano / 02-4120360 or 02-415640 / Telefax: 02-4121249

No. 199BRO  
188CAH150K

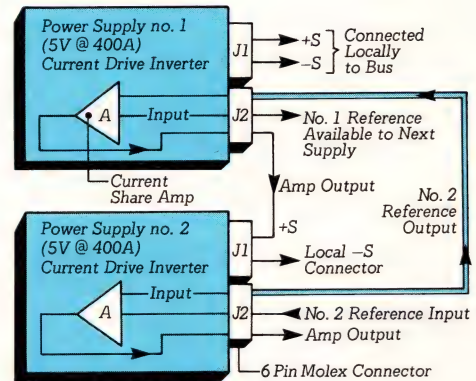




# Perfect Harmony!

## Equal Sharing / N+1 / Reliability!

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- ✓ International AC Input
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- ✓ SELV Magnetics
- ✓ Thermal Protection
- ✓ Fully Regulated
- ✓ Certified Safety

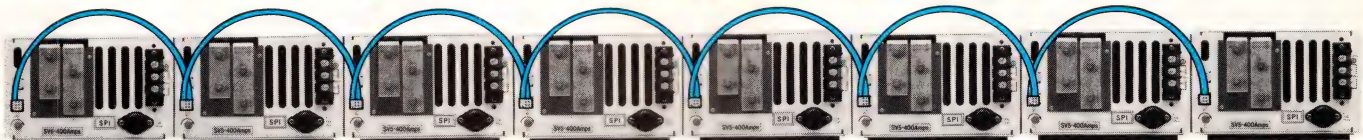


# SWITCHING POWER INC

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# Acromag has solutions for interfacing A/D, D/A and Digital I/O signals to the VMEbus.

Our extensive line of VMEbus-based products handles your interfacing applications for test and measurement, industrial control, or data acquisition.

If you need to interface with industrial sensors and industry standard field signals:

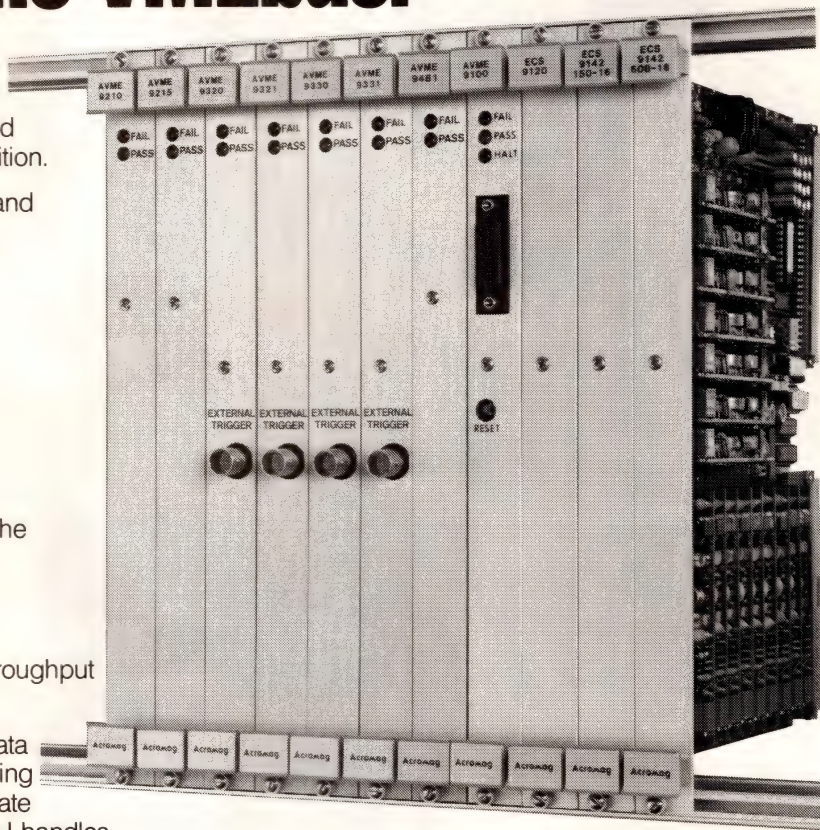
DC VOLTS OR CURRENTS  
MILLIVOLT  
THERMOCOUPLE  
RTD  
AC VOLTS OR CURRENTS  
STRAIN GAUGE  
PRESSURE  
FREQUENCY

We have total solutions from the field wiring to the VMEbus.

## PERFORMANCE

For basic A/D conversion, we've incorporated many operational features to improve overall throughput to your host processor.

For more advanced applications, Acromag's Data Acquisition Subsystem simplifies sensor interfacing and reduces host activity. So you can concentrate on processing the data while our on-board CPU handles routine tasks.



Function	In/Out	Max Signal Range**	Features	Product
High-Speed Analog I/O	16D/32SE*in 2 out, opt.	±10 in/out	12 Bit A/D, 67K chan/sec throughput 12 Bit D/A	AVME9320 AVME 9321
High-Res. Analog I/O	16D/32SE in 2 out, opt.	±10 V in/out	14 Bit A/D, 33K chan/sec throughput 12 Bit D/A	AVME 9330 AVME 9331
Analog Out	8 out	±10V, Vout 4-20mA, Iout	12 Bit D/A, 6 $\mu$ sec Vout, 25 $\mu$ sec Iout, throughput	AVME9210 AVME 9215
Data Acq. Controller	16D/32SE in, opt.	±10V	14 Bit A/D, 256 in, scans, linearizes, limit checks	AVME9100 AVME9110
Subsystem Expanders	16D/32SE in	±10V	High level expander	ECS9120
	16D in	±10V	Filtered inputs	ECS9121
	8D/16D in	-6 to +60mV -15 to +150mV Thermocouple	250V isolation, interface for TC, RTD, and Pressure with termination panels	ECS9142-60 ECS9142-150 ECS9142-60B
Digital I/O	64 in/out	0-30V in/out	8 in with latch and interrupt	AVME9480 AVME9481

\*SE - Single ended D - Differential

\*\*Most inputs and outputs have programmable ranges.

**Acromag**   
LEADER IN SIGNAL CONDITIONING

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CIRCLE NO 175

## SUPPORT PRODUCTS

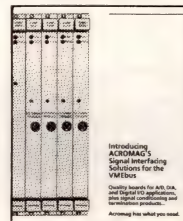
Acromag's termination products interface to your field wiring using screw terminals and to the VME backplane using ribbon cable. I/O connections are at the rear of the boards.

The modular, high-accuracy analog signal conditioning system connects to any of our VME high-level analog boards—like a termination panel. Available modules cover virtually all signal types and provide electrical isolation.

And we provide a comprehensive software support package for VERSAdos—with drivers, diagnostics, and a subroutine library in 'C'.

## QUALIFICATIONS

Let Acromag's 30 years of experience in signal interfacing benefit you. When you need to interface analog or digital signals to the VMEbus, call or write today. For more information request "Acromag's Signal Interfacing Solutions for the VMEbus" bulletin.

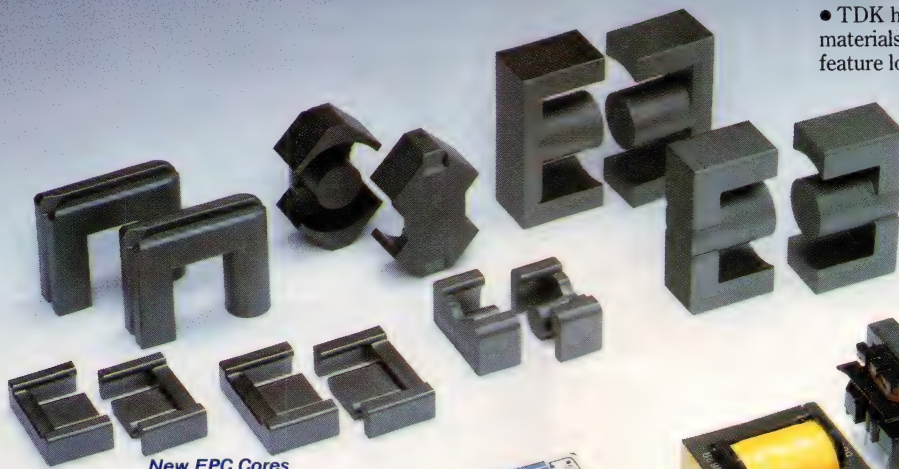




# TDK Has The Component Solutions To Fit Any Power Supply Challenge.

For frequencies above 100kHz, choose TDK Power Ferrite Cores.

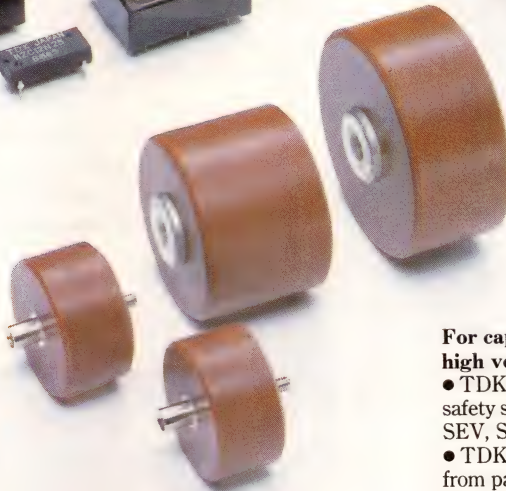
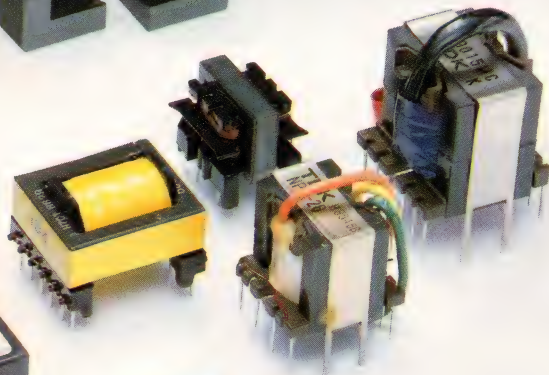
- TDK has newly developed 3 types of ferrite materials, H7C1, H7C4 & H3H. These materials feature low power loss and high flux density with outstanding electromagnetic characteristics.
- A wide range of reliable, TDK compact cores are available to meet all your power supply challenges, now including the new ultra-thin EPC core for low profile design.



New EPC Cores

From high power transformers to on-board DC to DC Converters, TDK offers top efficiency and operating stability.

- TDK low loss, high flux density Ferrite Cores are built into our highly efficient power transformers and inductors.
- TDK On-Board DC to DC Converters provide you with a choice of 0.3, 0.8, 1.5 and 3 watt power ratings. They're designed for high density mounting and maintain operating stability.



For capacitors from 400Vac to super high voltage 50kVdc, look to TDK.

- TDK Capacitors meet international safety standards, including UL, CSA, VDE, SEV, SEMKO, BS, etc.
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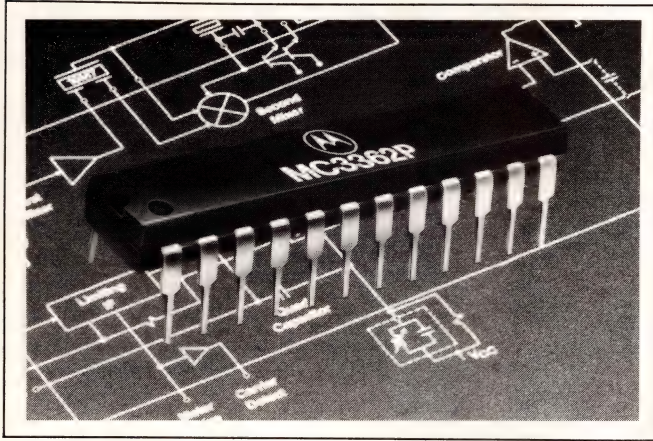


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# READERS' CHOICE

Of all the new products covered in EDN's **December 10, 1987**, issue, the ones reprinted here generated the most reader requests for additional information. If you missed them the first time, find out what makes them special: Just circle the appropriate numbers on the Information Retrieval Service card, or refer to the indicated pages in our **December 10, 1987**, issue.

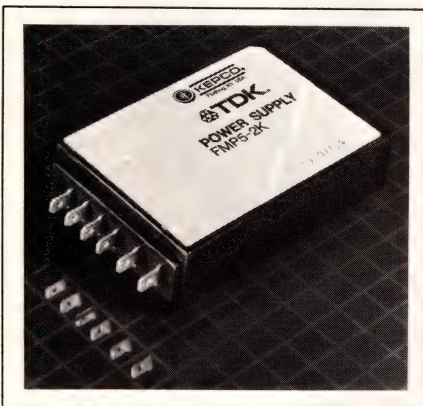


## ◀ FM RECEIVER

The MC3362 IC is a narrowband-FM, dual-conversion low-voltage (2V) receiver that incorporates all essential VHF-receiver functions, from the antenna input to the audio preamp output (pg 304).

**Motorola Inc.**

**Circle No 605**



## ▲ SWITCHING MODULES

FMP Series single-output switching modules come in low-profile, plastic-encased packages (pg 205).

**Kepeco Inc.**

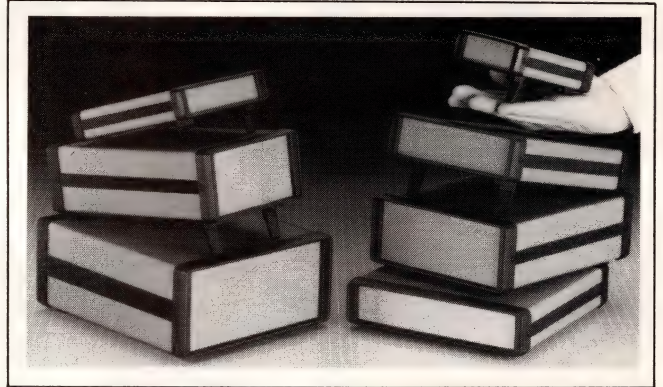
**Circle No 604**

## C COMPILER

Turbo C is a C editor, compiler, and linker that runs on the IBM PC and compatibles (pg 179).

**Borland International.**

**Circle No 603**

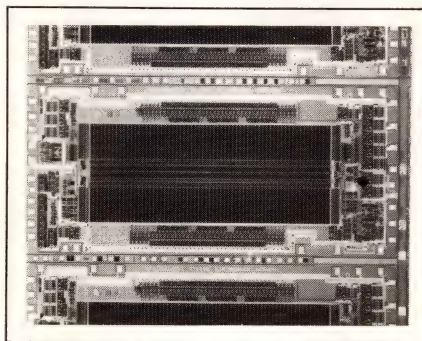


## ▲ ALUMINUM ENCLOSURES

The SL Series consists of seven small aluminum enclosures that provide EMI shielding and help to dissipate heat (pg 115).

**Tracewell Enclosures.**

**Circle No 602**



## ◀ CMOS FIFO

The MK4505 is an edge-triggered, latched, expandable, and cascable FIFO buffer that offers a 15-nsec access time (pg 59).

**Thomson Components-Mostek Corp.**

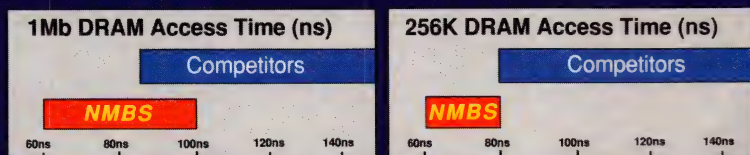
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			PLCC	Production
			C-DIP	Production
AAA1M100 1Mb	100/120 (ns)	256Kx4 1Mbx1	P-DIP	Production
			SOJ	Production
			ZIP	Production
AAA1M200 1Mb	60/70/80 (ns)	256Kx4 1Mbx1	P-DIP	2Q88
			SOJ	2Q88
			ZIP	2Q88

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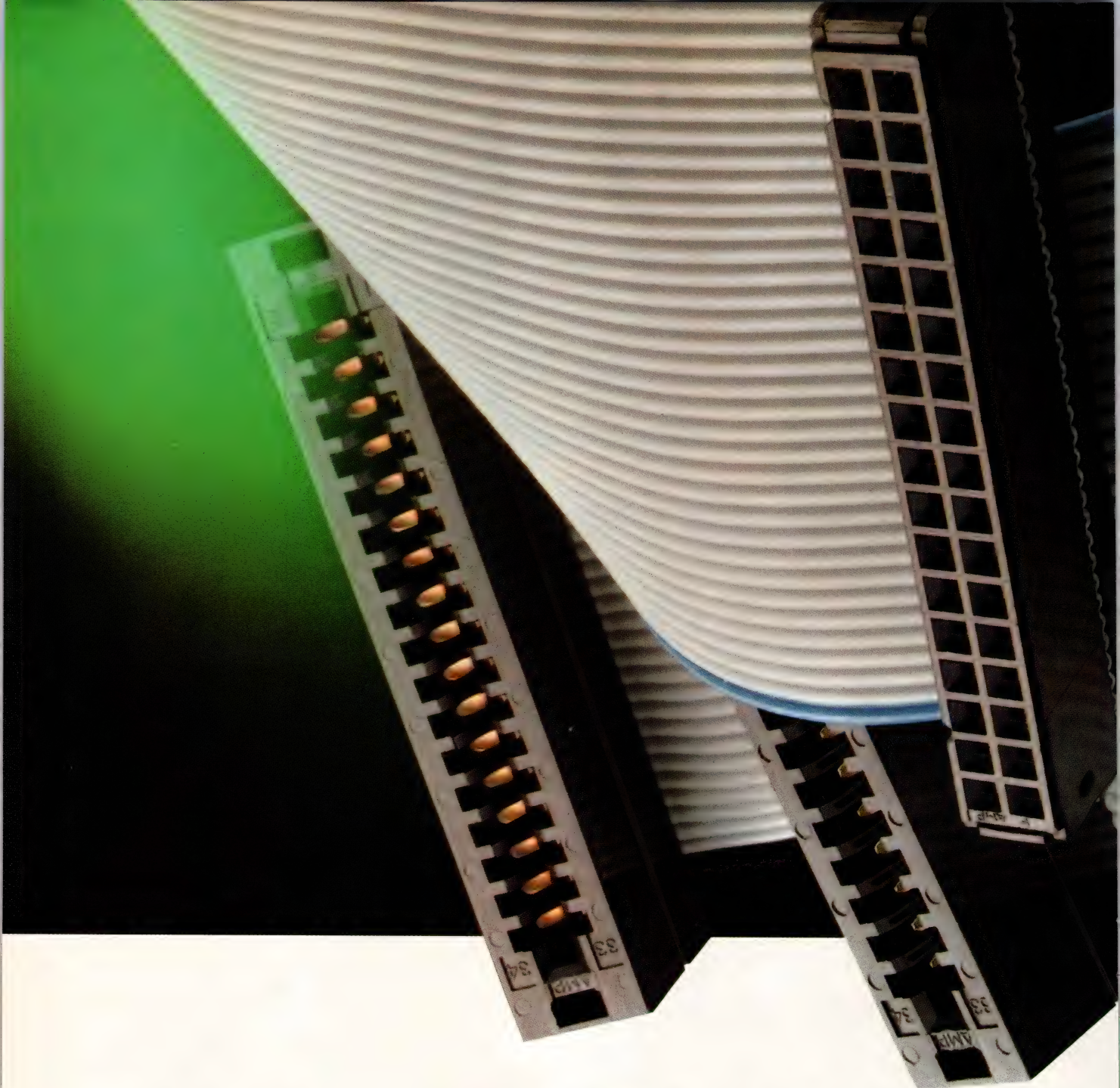
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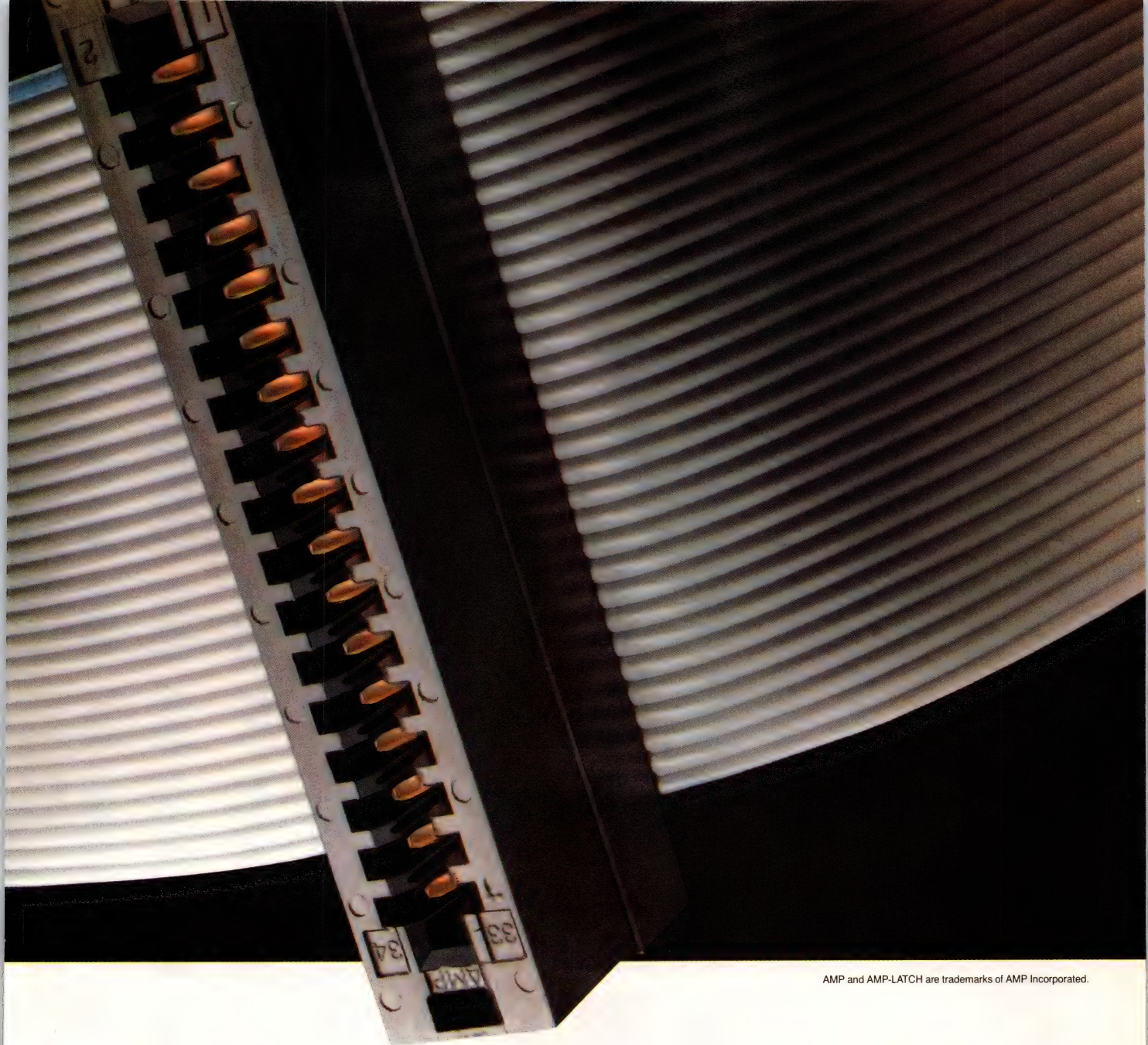






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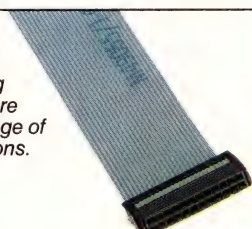
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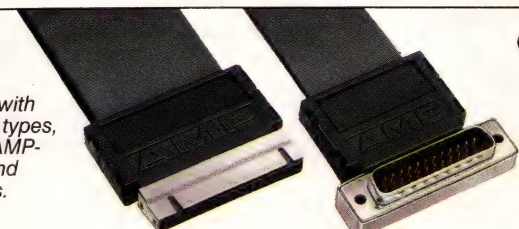
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# LEADTIME INDEX

Percentage of respondents

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
<b>TRANSFORMERS</b>								
Toroidal	8	58	17	17	0	0	5.7	9.3
Pot-Core	0	50	25	17	8	0	8.2	9.4
Laminate (power)	6	39	33	17	5	0	7.8	8.7
<b>CONNECTORS</b>								
Military panel	0	0	67	17	16	0	12.2	11.5
Flat/Cable	17	44	28	11	0	0	5.3	6.6
Multi-pin circular	10	40	20	20	10	0	8.0	10.0
PC (2-piece)	0	33	45	22	0	0	8.0	7.3
RF/Coaxial	13	40	13	27	7	0	8.1	6.4
Socket	6	67	11	11	5	0	6.0	5.3
Terminal blocks	25	45	15	10	5	0	5.4	5.6
Edge card	19	44	19	12	6	0	6.3	6.3
D-Subminiature	13	40	33	7	7	0	6.6	6.2
Rack & panel	0	45	33	11	11	0	8.6	6.8
Power	0	29	29	28	14	0	11.2	7.2
<b>PRINTED CIRCUIT BOARDS</b>								
Single-sided	0	74	21	5	0	0	4.7	5.1
Double-sided	0	46	50	4	0	0	6.0	6.9
Multi-layer	0	23	69	8	0	0	7.4	7.9
Prototype	5	85	10	0	0	0	3.4	3.5
<b>RESISTORS</b>								
Carbon film	35	45	20	0	0	0	3.0	3.6
Carbon composition	28	43	19	10	0	0	4.3	3.1
Metal film	15	50	35	0	0	0	4.3	4.4
Metal oxide	11	56	22	11	0	0	5.2	4.8
Wirewound	4	46	32	14	4	0	7.2	7.2
Potentiometers	7	55	31	7	0	0	5.2	6.4
Networks	16	37	32	10	5	0	6.6	4.7
<b>FUSES</b>								
	54	38	8	0	0	0	1.8	3.8
<b>SWITCHES</b>								
Pushbutton	11	72	11	6	0	0	3.9	6.0
Rotary	5	67	11	17	0	0	5.5	7.3
Rocker	6	59	23	12	0	0	5.5	5.7
Thumbwheel	0	69	15	16	0	0	5.7	8.4
Snap action	0	64	29	7	0	0	5.3	5.6
Momentary	7	60	26	7	0	0	5.0	5.6
Dual in-line	0	50	20	30	0	0	7.8	6.4
<b>WIRE AND CABLE</b>								
Coaxial	23	68	9	0	0	0	2.8	3.3
Flat ribbon	26	42	32	0	0	0	3.8	4.0
Multiconductor	25	50	25	0	0	0	3.5	4.6
Hookup	23	65	12	0	0	0	2.9	3.1
Wire wrap	38	54	8	0	0	0	2.2	4.8
Power cords	28	56	12	4	0	0	10.8	4.5
<b>POWER SUPPLIES</b>								
Switcher	6	41	29	24	0	0	7.2	10.1
Linear	0	55	27	18	0	0	6.6	9.5
<b>CIRCUIT BREAKERS</b>								
	7	33	27	33	0	0	8.3	8.2
<b>HEAT SINKS</b>								
	17	46	33	4	0	0	4.7	6.2
<b>RELAYS</b>								
General purpose	13	67	12	8	0	0	4.3	6.9
PC board	0	79	0	21	0	0	5.7	8.5

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
<b>RELAYS</b>								
Dry reed	0	40	40	20	0	0	7.5	8.9
Mercury	20	40	40	20	0	0	4.4	8.8
Solid state	0	54	31	15	0	0	6.5	7.5
<b>DISCRETE SEMICONDUCTORS</b>								
Diode	32	42	19	7	0	0	3.8	7.8
Zener	35	35	15	15	0	0	4.7	8.8
Thyristor	8	38	31	23	0	0	7.2	9.5
Small signal transistor	37	32	21	10	0	0	4.3	8.8
MOSFET	6	44	28	22	0	0	7.0	8.0
Power, bipolar	15	31	39	15	0	0	6.4	7.5
<b>INTEGRATED CIRCUITS, DIGITAL</b>								
Advanced CMOS	0	50	33	17	0	0	6.8	9.3
CMOS	10	38	38	14	0	0	6.4	8.7
TTL	21	42	16	21	0	0	5.8	5.7
LS	19	48	19	14	0	0	5.2	5.9
<b>INTEGRATED CIRCUITS, LINEAR</b>								
Communication/Circuit	8	42	33	17	0	0	6.5	8.9
OP amplifier	17	33	22	28	0	0	7.1	7.8
Voltage regulator	11	42	26	21	0	0	6.6	6.8
<b>MEMORY CIRCUITS</b>								
RAM 16k	0	46	27	27	0	0	7.8	7.3
RAM 64k	0	47	27	26	0	0	7.7	7.7
RAM 256k	0	20	47	33	0	0	9.5	10.0
RAM 1M-bit	0	20	30	40	10	0	11.8	11.1
ROM/PROM	9	36	18	37	0	0	8.2	8.7
EPROM 64k	0	36	43	21	0	0	7.8	8.5
EPROM 256k	0	36	36	28	0	0	8.4	9.7
EPROM 1M-bit	0	22	45	33	0	0	9.4	13.5
EEPROM 16k	0	40	30	30	0	0	8.3	9.4
EEPROM 64k	0	36	37	27	0	0	8.3	9.6
<b>DISPLAYS</b>								
Panel meters	8	38	46	8	0	0	6.0	7.2
Fluorescent	0	12	38	50	0	0	11.1	13.0
Incandescent	0	33	34	33	0	0	8.8	8.9
LED	18	32	41	9	0	0	5.6	6.8
Liquid crystal	0	10	40	50	0	0	11.3	9.8
<b>MICROPROCESSOR ICs</b>								
8-bit	28	27	18	27	0	0	6.5	7.8
16-bit	8	50	17	25	0	0	6.7	9.1
32-bit	8	42	25	25	0	0	7.1	8.9
<b>FUNCTION PACKAGES</b>								
Amplifier	0	50	38	12	0	0	6.4	10.2
Converter, analog to digital	0	31	46	23	0	0	8.2	9.8
Converter, digital to analog	0	43	29	28	0	0	8.0	10.7
<b>LINE FILTERS</b>								
	0	63	12	25	0	0	6.8	7.6
<b>CAPACITORS</b>								
Ceramic monolithic	21	32	37	10	0	0	5.5	6.3
Ceramic disc	26	30	29	15	0	0	5.6	6.5
Film	9	45	32	14	0	0	6.0	7.5
Aluminum electrolytic	12	42	27	19	0	0	6.4	7.2
Tantalum	15	41	29	15	0	0	5.9	7.1
<b>INDUCTORS</b>								
	0	44	31	25	0	0	7.7	7.6

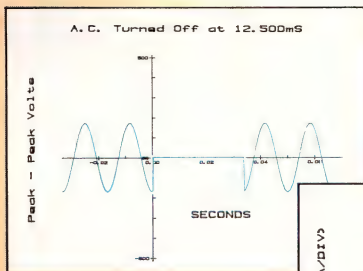
Source: Electronics Purchasing magazine's survey of buyers





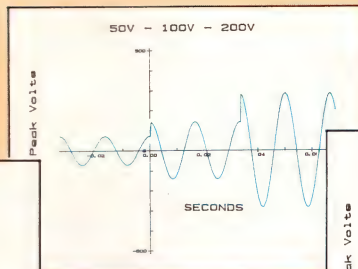
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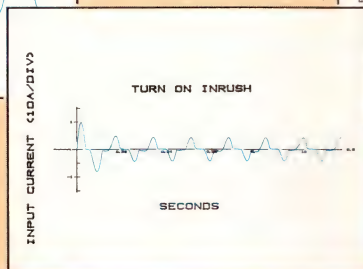
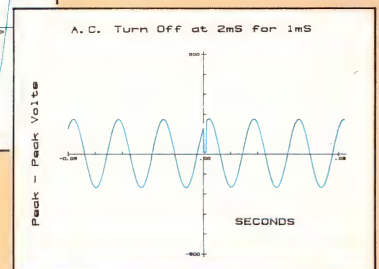


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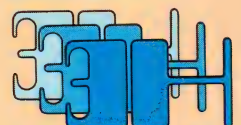
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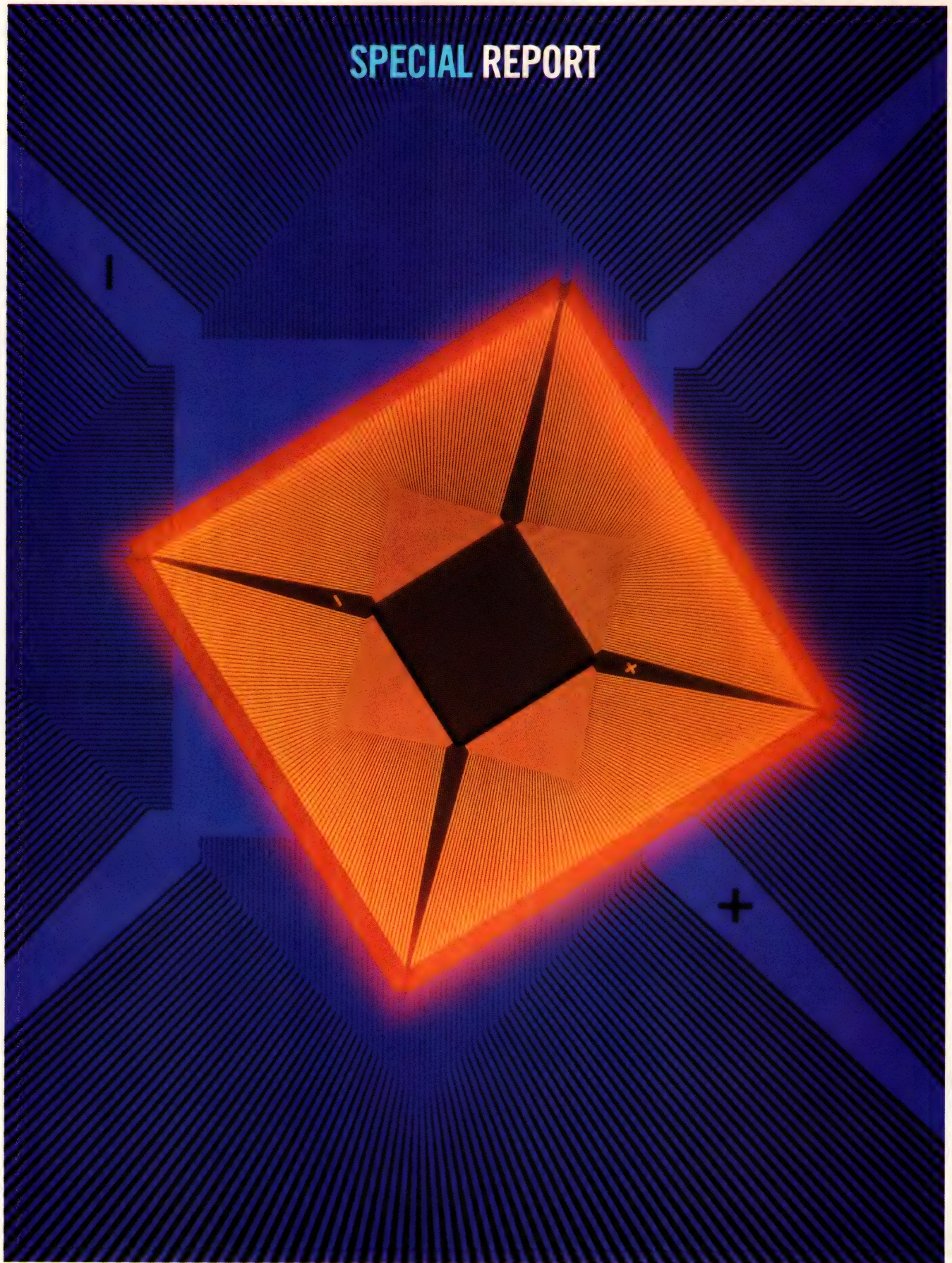
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## SPECIAL REPORT



*With new processing technologies, you can realize the high-density packaging required to develop today's electronic systems.  
(Photo courtesy DuPont)*





# MATERIALS AND HARDWARE

---

Tom Ormond, *Senior Editor*

High density and performance are goals for today's VLSI- and SMT-based designs. Fortunately, advances in materials other than silicon are keeping pace with advances in integrated circuits. Innovative hardware is making it easy to mount, cool, interconnect, and shield VLSI- and SMD-populated assemblies.

---

VLSI devices are achieving increasingly high levels of performance, and surface-mount technology makes possible significant increases in circuit densities. Equally important, however, are the advances in material and hardware areas. These advances are converting the promises of VLSI and SMT into manufacturable, cost-effective products.

This report will highlight innovations in six nuts-and-bolts areas of system design:

- Fabrication processes, which are yielding improved resistance materials for high-resolution, low-current trimmers, and which are offering improved packaging techniques for microwave circuits (pg 150).
- Wired circuit boards, which can operate at gigahertz frequencies (pg 151).
- Molding technology, which yields not only unique pc-board configurations but also enclosures that you can tailor to your application (pg 152).
- Thermal-management technology, which can help you remove heat from dense, high-performance circuits (pg 154).
- Connectors (both fiber optic and electrically conductive), which are easing the interface to high-density circuits (pg 155).
- Shielding, which can help you ensure electromagnetic compatibility at the enclosure or component level (pg 158).



*Designed to efficiently transfer heat from pc-board components, thermal planes from Aavid are particularly well suited for use in sealed card cages that contain closely spaced boards.*



Although such areas rarely receive their just due when it comes to press coverage, they are critical if you hope to successfully guide your design through the production phase of the product-development cycle.

## • Fabrication processes

Today's variable-resistance devices (trimmers) typically include wirewound, bulk-metal, or cermet-film resistive elements. Devices from this last category have traditionally served applications requiring high resolution: Cermet-film elements offer essentially infinite resolution. In contrast, wirewound and bulk-metal elements both exhibit step-type resolution characteristics—because of the discrete windings around a mandrel in the former case and, in the latter case, because the photoetching process used to produce bulk-metal elements generally yields a serpentine pattern.

Cermet has exhibited a drawback, however. Oxidation can plague thick-film cermet trimmers when they're exposed to low-microampere (dry-circuit) currents. Cermet is essentially a metal-oxide ink. Dry-

circuit current levels cannot break down the oxidation layer (which forms at the junction of the wiper and the resistive element), and as a result, long-term cermet-trimmer stability degrades.

To better adapt cermet to dry-circuit applications, Bourns has developed what it calls Palirium technology, in which islands of precious metal (usually a low-resistance gold compound) are deposited on a thick-film cermet element and cured at high temperatures. A wire wiper makes contact with the metal pads on the cermet resistance element. The wiper, made up of multiple contact points, reduces contact resistance by creating parallel current paths across adjacent islands.

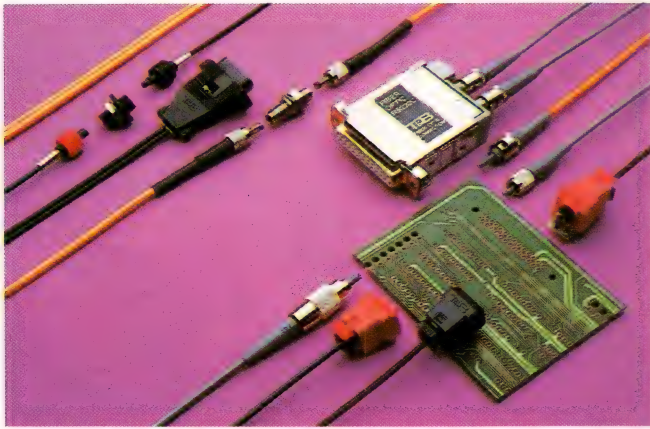
The Bourns Trimpot II HPS trimmers are the first devices to employ this new technology. Their resistance values range from 0.5 to 100 k $\Omega$  with a tolerance of  $\pm 10\%$ , and their resolution ranges from 0.15 to 0.35%. In company tests for contact-resistance variation, which were run at a current level of 5  $\mu\text{A}$  on nominally 2-k $\Omega$  elements at 125°C over 2000 hours, drift was less than 0.5%. These results represent a greater than 300%



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*In applications involving dry-circuit current levels, oxidation layers seriously degrade the long-term stability of conventional cermet trimmers.*

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*Although simple termination and easy maintenance are key features of the Pre-Cap fiber-optic connectors from Thomas & Betts, they are also high-performance devices. Their mean insertion loss equals 0.12 dB; the standard loss deviation measures 0.016 dB.*

performance improvement over conventional cermet variable-resistance elements. Indeed, these specs compare favorably to those of the more costly bulk-metal trimmers.

#### Handling microwave circuit needs

Other advances in film-deposition techniques are benefiting multilayer microwave circuits. DuPont has developed four proprietary technologies—PCM, PCS, LCM, and PPM- $\beta$ —which it uses to fabricate microwave modules that accommodate surface-mount devices and thick-film resistors. The modules feature ceramic construction. DuPont uses photoforming techniques to provide conductor lines with square edges and smooth surfaces.

PCM (photoformed ceramic module) technology is a copper-based multilayer technology designed to provide excellent conductivity and via geometry. Resolution for lines and spaces equals 2 and 3 mils, respectively, and vias can have 4-mil diameters.

PCS (photoformed ceramic substrate) technology, which is compatible with PCM, provides thin-film accuracy and control without the costs associated with conventional single-layer processes. PCS produces very-fine-line conductor traces using a polymer emulsion that becomes tacky when exposed to light. In the PCS process, the tacky area is toned using a conductor or oxide powder and then fired to set the pattern. PCS resolution approaches or exceeds that of thin-film technology: Resolution for lines and spaces equals 2 mils.

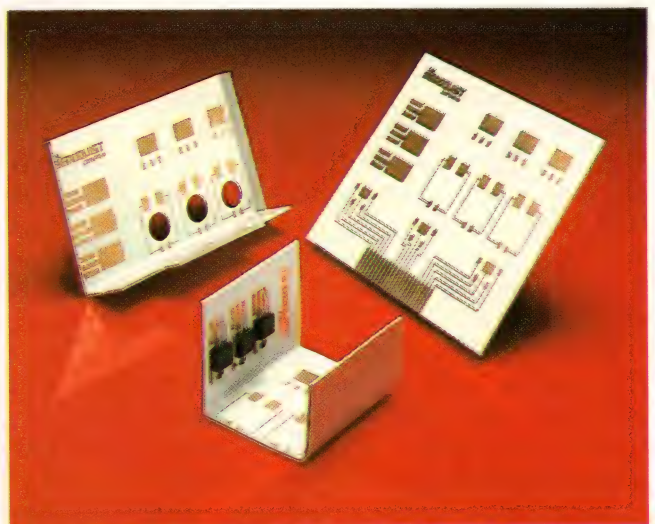
LCM (laminated ceramic module) technology is a low-temperature co-fired ceramic technology that uses

a proprietary dielectric film and specially formulated gold, silver, silver/palladium, or copper compositions. The technology provides a cost advantage vs thick-film multilayer schemes, and it outperforms high-temperature co-fired ceramics. LCM technology produces a dense hermetic structure that you can personalize by using existing thick-film or PCM technology.

Finally, the PPM- $\beta$  (photoformed plastic module) technology, which is compatible with either rigid or flexible circuitry, produces 5-mil lines and 25-mil pads on a variety of substrates (as large as 12×18 in.) with as many as four layers. In the fabrication cycle, a proprietary process plasma-etches a dielectric material to form blind and buried vias. These vias are more tolerant of thermal cycling than plated vias are, so PPM- $\beta$  technology minimizes the problems that can occur when wave-soldering surface-mounted components. PPM- $\beta$ 's polyimide dielectric offers a low dielectric constant and its bulk copper foil produces high conductivity.

#### • Wired circuit boards

The increasing number of high-speed designs employing ECL, advanced Schottky logic, high-speed CMOS, and even gallium arsenide are producing new challenges in the areas of circuit density and signal propagation. Kollmorgen Corp's Multiwire Div has developed a discrete wiring technology that offers



**Featuring electrical characteristics that match those of ceramic materials,** Thermal-Clad substrates from Berquist can serve as isolated mounting media for either packaged or unpackaged heat-generating devices. The substrates feature three laminated layers: a base plate (usually copper or aluminum) bonded with an epoxy-based, thermally conductive dielectric to a circuit layer (either copper or aluminum foil).



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*Photoforming techniques are beginning to bridge the gap between the accuracy of thin film and the cost advantages of thick film.*

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solutions to many of the challenges that designers face when striving to realize high-speed circuits.

The Multiwire circuit boards feature a customized pattern of wires (4 or 6 mils) laid down on an adhesive-coated substrate. Polyimide insulation on the wires lets them cross without shorting (and eliminates the need for vias in internal layers), thereby increasing packaging density: A Multiwire board with one or two layers of wiring can readily replace a more expensive multilayer board.

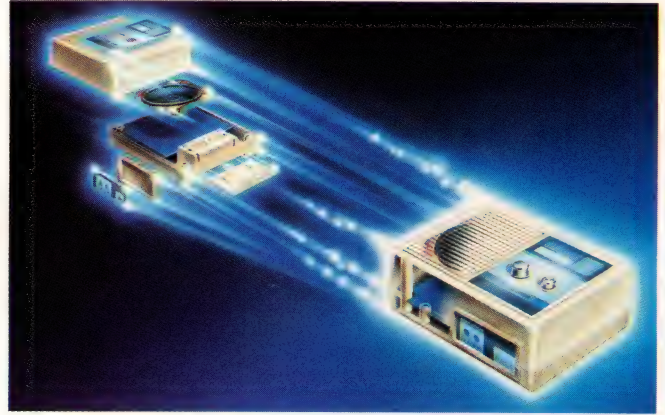
The Multiwire board-fabrication process begins with a standard, copper-clad FR-4 base material. The copper-clad base laminate is then imaged and etched according to a format drawing. The format determines both the ground planes for power distribution and the board's controlled impedance. Adhesive material applied to the board provides a base for the placement of wires. The adhesive insulates the power and ground planes and serves as a foundation for the permanent interconnections.

A computer-driven numerically controlled wiring machine then writes insulated wires in a predetermined, repeatable pattern in accordance with the customer's net list. Each wire begins and ends at a hole location. Next, the wires are pressed into the adhesive and encapsulated by a cover layer of epoxy glass. This process locks every wire securely in place. Holes drilled at each plated-through-hole location serve a dual role, providing a junction for each wire as well as mounting holes for components.

The board then undergoes a chemical cleaning process, and insulation is removed from the wire ends. Copper is then plated in the holes to mechanically and electrically connect each wire to the wall of the hole. This interconnection exceeds IPC and military standards for bond strength and withstands multiple soldering and desoldering without damage to the hole barrel or interconnect.

Multiwire's Coaxe board illustrates the capabilities of the technology. By eliminating several problems detrimental to high-speed performance (propagation delays, crosstalk, reflections, and ground currents), the board allows designers to achieve speeds to 20 GHz.

Although the Coaxe circuit board resembles other Multiwire boards in appearance, its performance at gigahertz frequencies is quite different. Its characteristic impedance is exactly matched to application requirements. Time delay can be reduced to 1.2 nsec/ft. The boards'  $2 \times 10^{-4}$  dissipation factor results in attenuations as low as 4.9 dB/ft at 1 GHz.



*The flexibility available with molding techniques allows Amerex to provide standard enclosures with custom molded options.*

The Coaxe board combines the best features of coaxial cables and the packaging simplicity of pc boards. It features a coaxial wire that's small enough to be built into the board. As a result, it offers true 50 $\Omega$  coaxial interconnections between circuit components. The 50 $\Omega$  coaxial lead is embedded in the ground plane; you can specify coaxial wires for every interconnect on the board. Embedding the shielded leads in the ground plane minimizes return currents. The ground plane also serves as a heat sink for mounted chips. The Coaxe board accommodates either through-hole or surface-mounted components.

## • Molding technology

Traditional pc boards have one primary mission—to mechanically support and electrically interconnect components on a 2-dimensional surface. Designers have had to use other components and structural elements to connect the pc board to the rest of the system. Now, molded circuit interconnects offer a new approach for packaging electronic components. These interconnects employ injection-molded thermoplastic parts that are selectively metallized. They can incorporate pc boards, connectors, chip carriers, and mechanical and structural elements.

Molded circuit interconnects are made from engineering-grade thermoplastics such as polysulfone, polyethersulfone, polyetherimide, and polyarylsulfone. The characteristics of these resins provide maximum continuous run temperatures as high as 180°C and heat-deflection temperatures to 210°C. Electrical parameters are also impressive: Resistivity is  $10^{+10}$   $\Omega$ -cm, and in the gigahertz frequency range the dielectric constant is approximately 2.8.





*With permeabilities ranging to 350,000, Bomco's M $\mu$ Shield material is designed for applications in which EMI could be catastrophic to sensitive instruments.*

With molded boards, thickness control is far superior to that of epoxy-fiber-glass laminates and is uniform over the entire board surface—tolerances reach  $\pm 0.001$  in. Molded-in holes are clean and free of drilling debris. Hole diameters can be as small as 0.3 mm (12 mils) with tolerances of  $\pm 0.013$  mm ( $\pm 0.5$  mil). The molding process places no limit on the form of holes and cutouts.

However, because of the flow characteristics of available resins and the molding pressure required to fill the molds, board sizes are currently limited to about 150 in<sup>2</sup>. Moreover, the technology is most economical in high-volume applications (typically, more than 40,000 pieces) where you can amortize the cost of making the mold over the lifetime of the part. In addition, molded circuits are not very forgiving when it comes to engineering changes: Changes in circuit layout, for example, require changes in the mold. Finally, molded circuits are not compatible with multilayer constructions.

### **Bringing the technology to market**

Triquest and Elite Circuits are two companies working together to develop molded circuit boards. Triquest builds the molds and produces the substrate boards; Elite provides the metallization and other finishing procedures.

Another molding-technology company is Pathtek; it is involved in volume production of a molded LED holder and interconnect for an electronic typewriter. The molded device uses the company's Mold-n-Plate

process (a 2-shot imaging and selective-metallization system) to form circuit patterns on molded structures. The part aligns four LEDs in a molded holder, which serves as a mounting mechanism. By incorporating 2-sided, plated-through-hole circuitry into the plastic molding, this device replaces a single-sided circuit board and consolidates three components into one package.

Although the molded part and its conventional equivalent function identically, the molded part offers advantages in weight reduction and overall assembly costs. Weight, parts count, and subassembly labor operations for the molded and conventional implementations are 9.9g vs 11.5g, six parts vs eight parts, and three operations vs six operations.

### **An inside look at today's enclosures**

Molding technology doesn't stop with boards. It's also finding application in the enclosure market, where modularity and versatility are key driving forces. A casual observer might miss most of the innovations in enclosure design because many of the advances are quite subtle.

The past few years have seen minimal alterations in basic enclosure design. Portable molded enclosures still come in two basic styles: the 1- or 2-piece clam-shell style, wherein users typically interface through the top surface; and the front/rear panel design, in which interfacing normally takes place through the panel sections. When you look beyond the basic styles, howev-



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*The high-speed active devices available today pose a number of problems for pc-board designers.*

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er, you'll find that vendors are offering a variety of enclosure features that are designed to let users more effectively package their products.

One development has been the introduction of specialty enclosures that include battery compartments. More recent innovations, from companies like Amerex, include display-window enclosures, speaker-grill enclosures, and low-profile enclosures. All of these off-the-shelf specialty units incorporate molded-in features that can make your product look like it's enclosed in a custom housing.

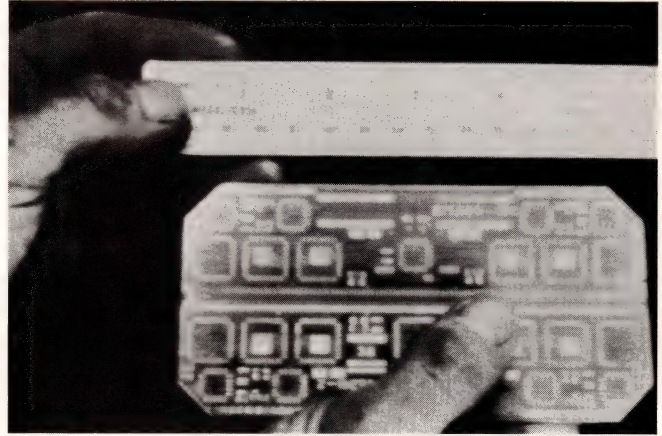
### • Thermal management

Board-level thermal management has been a major design consideration for many years. Today, though, designers are striving to cram more and more circuitry into smaller and smaller packages, and the resulting increase in power densities is making effective thermal management even more critical. Indeed, heat dissipation can reach levels that standard pc-board materials cannot handle effectively. Fortunately, vendors of substrate materials are addressing these dissipation problems.

Thermo-Clad substrates from Berquist serve as an isolated mounting medium for either packaged or unpackaged heat-generating devices. The substrates feature three laminated layers: a base plate (usually copper or aluminum) bonded with an epoxy-based, thermally conductive dielectric to a circuit layer (either copper or aluminum foil). This combination provides several important features in demanding surface-mount applications. It has electrical characteristics that match those of ceramic or epoxy-glass materials, but the composite substrate has much better thermal and physical characteristics than either material. Surface resistivity equals  $7 \times 10^9 \text{ M}\Omega$ , and thermal conductivity measures  $0.0136 \text{ W/cm/}^\circ\text{K}$ . In addition, TCE (thermal coefficient of expansion) ranges from 8 to 25 ppm/ $^\circ\text{C}$  over an operating range of  $-36$  to  $+100^\circ\text{C}$ .

The dielectric layer holds the key to Thermal-Clad substrate performance. It rapidly transfers heat from the metal etched-circuit layer to the metal base plate while it simultaneously electrically isolates the two layers. The dielectric withstands processing temperatures as high as  $400^\circ\text{C}$  and features good breakdown performance—2000V for a 2-mil-thick layer.

The design flexibility of Thermal-Clad substrates is especially useful in die-mounted assemblies. Substrate dimensions can range from less than  $1 \text{ in}^2$  to  $10 \times 16 \text{ in}$ . To satisfy special requirements, Berquist can also alter



*High density and reliability are possible with custom, multilayer ceramic substrates from DuPont. The Aegis part, suitable for multi-chip control boards, permits greater design freedom without sacrificing reliability.*

performance characteristics by thickening a layer or changing layer materials. You can, for example, specify substrates that feature a heavy copper circuit layer to handle high currents and provide better thermal spreading characteristics. You can also request a substrate whose dielectric layer withstands 4000V. In addition, Berquist can provide special base materials to optimize thermal expansion characteristics, for example.

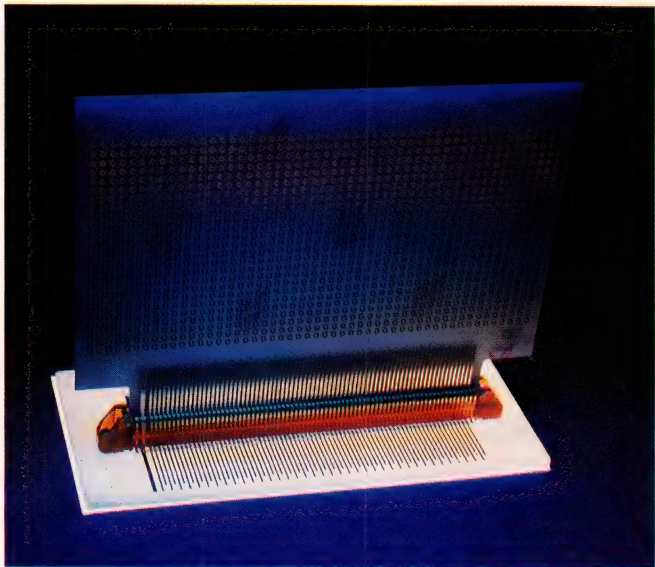
Aavid Engineering takes a more traditional approach to solving thermal-management problems with its pc-board thermal planes. These planes are designed to efficiently transfer heat from pc-board components to the cold wall of a card cage and are particularly well suited for use in sealed card cages that contain closely spaced boards.

Made of aluminum or copper in thicknesses from 0.02 to 0.1 in., the thermal planes are fabricated on numerically controlled equipment to achieve maximum hole-to-hole layout density. It's possible, for example, to achieve 0.09-in. holes on 0.1-in. centers—a pattern that's particularly useful for chip carriers, for which heat dissipation from central pins can often be a problem.

The thermal planes are available with a number of different finishes. Aluminum planes can be black-anodized or finished with gold chromate. Copper planes are available with tin or nickel electroplating, black oxide, or a special high-emissivity dielectric coating that also has high thermal conductivity.

In addition to the basic thermal planes, Aavid also offers prepregged sheets that let you bond the thermal planes to the pc board. The planes are also available





*Based on a design employing shape-memory alloys, these impedance-matched, high-density connectors from Beta Phase offer a combination of zero insertion force and high contact force. In addition, you can actuate the devices electrically.*

with epoxy-lined through holes to provide electrical insulation. The planes work with pc boards that have all kinds of through-hole components—ICs, transistors, resistors, diodes, rectifiers, and bridges.

The thermal planes add rigidity to the board and help to resist shock and vibration. Aavid provides complete design support for custom thermal-plane products. Using CAD equipment to analyze your board's thermal characteristics, the company can provide a plane that is optimum for an individual application.

## • Connectors

Manufacturers of electrical connectors are offering devices with contact spacings in the millimeter range to help you get signals into and out of high-density boards. Fiber-optic-connector manufacturers are offering devices that are easy to terminate but that don't sacrifice performance. In addition, some manufacturers are taking a systems approach to product design and development.

Molex is one connector manufacturer that's emphasizing the systems approach. To reduce customers' costs, Molex is currently using robots to interconnect connectors to pc-board headers, to insert single-in-line modules into its SIMM sockets, and to insert daughter boards into edge connectors.

Increasing circuit densities are driving the trend toward metric center-to-center pin spacings. Although

the incremental difference between connectors with 1.25-mm and 0.050-in. contact spacings might seem trivial (the standard 0.050-in. center-to-center connector requires about one mil more space per position than the 1.25-mm connector does), the space savings can be significant for a 30- or 40-position connector.

Molex has developed a 1.25-mm board-to-board hinged connector—a 2-piece system with a mated height and width of 10.3×6.7 mm. Aside from helping designers maximize circuit-board density, the connector facilitates pc-board maintenance by allowing you to easily access the board surface. The connector mates on the coplanar (or board-edge to board-edge) axis, allowing you to rotate the board by as much as 90°. The connector also mates in the reverse direction to accommodate boards that are mounted in parallel.

The connector is basically designed for use on pc boards that house components requiring adjustments (potentiometers or trimmer capacitors) as the boards pass down an assembly line. The hinged connector uses a reliable, high-pressure tuning-fork-type contact system. The connectors feature plated phosphor bronze contact terminals. Solder tails are arranged in a staggered pattern to simplify the soldering process and to improve the connector's mechanical stability. Kinks in the solder tails keep the connectors properly positioned during soldering.

Mating and rotation lifetimes for these hinged connectors are 30 and 50 cycles, respectively. The connectors are available in 4- to 20-position sizes (even numbers only). The polyester housings have a 94V-0 UL flammability rating. Contacts are rated for 125V at 1A.

Pre-Cap Series connectors from Thomas & Betts are compatible with SMA, ST, and FC fiber-optic-connector designs. Although simple termination and easy maintenance are key features of the connectors, they are high-performance devices nevertheless. Mean insertion loss equals 0.12 dB, and standard loss deviation measures 0.016 dB.

The connectors consist of a precision injection-molded ferrule assembly, a bayonet-type nut, a compression spring, and a retaining coupler ring. The ferrule is keyed and spring-loaded into the coupler to provide repeatable connector performance. The ferrule features a borosilicate-glass capillary, a zinc die-casted insert, and an injection-molded, self-reinforced thermotropic liquid-crystal polymer. The capillary measures 1×10 mm, has a 128- $\mu$ m-diameter center hole (with a +1/-0- $\mu$ m tolerance), and features a beveled entry on one end to ease fiber insertion. The connector manufac-



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*Molded circuits offer designers an easy way to upgrade the packing density of a pc board.*

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turing process positions the capillary and the zinc insert within the molding die; the polymer is then injected to form the finished ferrule assembly.

Connector installation is quite simple. After preparing the cable's end, you simply place a small amount of medium-viscosity epoxy on the fiber and buffer and inject a low-viscosity epoxy into the ferrule. You then insert the fiber into the connector body and hold the cable in place by crimping the cable strength members. Next, you apply epoxy to the cavity of the strain-relief boot and then slide the boot onto the connector. After the epoxy cures, you scribe and break the fiber and then polish the interface.

The polishing operation produces a mirror-like finish on the fiber and the glass capillary. The polishing process removes only glass (rather than glass and ceramic, as is typical of many other connector-polishing operations), so there's no need to constantly monitor for fiber wear. The result is shorter termination time. Moreover, it's almost impossible to overpolish the ferrule tip.

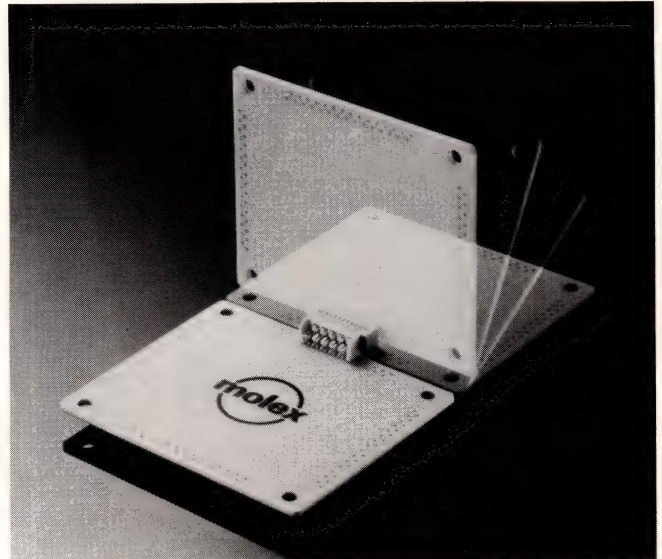
#### **A connector that never forgets**

Miracle wire and wonder wire are just a few of the names given to a group of alloys whose potential for commercial applications is yet to be realized. Known as shape-memory alloys (SMAs), these metals have a physical structure that, through the application of heat, can be unlocked, rearranged, and programmed to take on new shapes. Forces exerted during the reshaping transition can be tremendous—as much as 50,000 psi.

Although SMAs were introduced more than 20 years ago, their inherent advantages were not fully exploited because of fabrication difficulties: The metals often popped back into their original shape during the manufacturing process, breaking equipment. In addition, batch-to-batch consistency was poor. In the last few years, however, manufacturers have overcome these problems, making it possible to economically realize the commercial potential of the metals.

About 20 alloys have shape-memory properties, but only a few—copper zinc aluminum, copper zinc nickel, and nickel titanium—are practical for commercial applications. The nickel titanium alloys are the most promising because they offer the best overall performance characteristics. They have twice the memory and are far more resistant to corrosion and cracking than are other SMAs, and they are lightweight and nearly as elastic as rubber (depending on the nickel titanium combination).

Beta Phase offers a line of pc-board connectors that



*Featuring a 1.25-mm contact-to-contact spacing, these hinged connectors from Molex use a high-pressure tuning-fork-type contact system and a polyester housing that has a 94V-0 flammability rating.*

use this nickel titanium alloy. These connectors offer a combination of impedance-matched, high-density contacts, zero insertion force (ZIF), and high contact force. They allow you to make ZIF connections on three edges of a pc board. In addition, you can remotely or locally actuate the devices electrically—there's no need to physically access the connector. The connector can also function as a card guide and stiffener, providing good mechanical support for the board.

The connector consists of three basic parts—a shape-memory element, a closing spring, and flexible-film circuitry that includes the contact pattern and a built-in heater. When you trigger the heater, the shape-memory element moves toward its original flat shape, engaging and opening the contact-closing spring. After inserting the board, you remove power from the heater. The shape-memory element closes, engaging the contacts with high normal forces—100g/contact in a typical connector. The polyimide-film flexible circuitry meets military standards.

Beta Phase's connectors offer a number of features. The use of flexible circuitry allows for 0.01-in. contact-trace spacings, and it's also possible to mix trace widths and center spacings to accommodate signal, power, and grounding needs. The connectors are also compatible with surface-mount applications. Because plastic molded bodies are not required for strength or support, each connector's profile, size, and weight are low. The use of shape-memory alloys also makes it easy to tailor



# Surface mounted components do a lot more than merely reduce size

Today's demand for smaller and smaller electronic systems has fostered the creation of a large number of surface mounted chip components. This has resulted in the more efficient utilization of available PCB space with the net result of vastly reduced product size. That's the obvious advantage of surface mount. But there's more than just the obvious.

**Improved electrical performance:** Smaller, leadless components with shorter interconnections result in reduced stray capacitance and lower inductance allowing much faster operating speeds, faster rise times and higher frequency response.

**Lowered manufacturing costs:** Significant savings are achieved through elimination of the necessity for drilling

and plating thru holes in PCB's and by reduction in the overall PCB size and number of layers required.

**Automated assembly:** Surface mounted components permit the use of the latest automated assembly techniques leading to greater product consistency, higher reliability, better yields and a faster production capability.

**Standardized designs:** Component and packaging standards reduce product design efforts.

**Shock and vibration resistance:** Due to their low mass, small size, and strong solder interconnects, surface mounted components have exceptional resistance to shock and vibration.

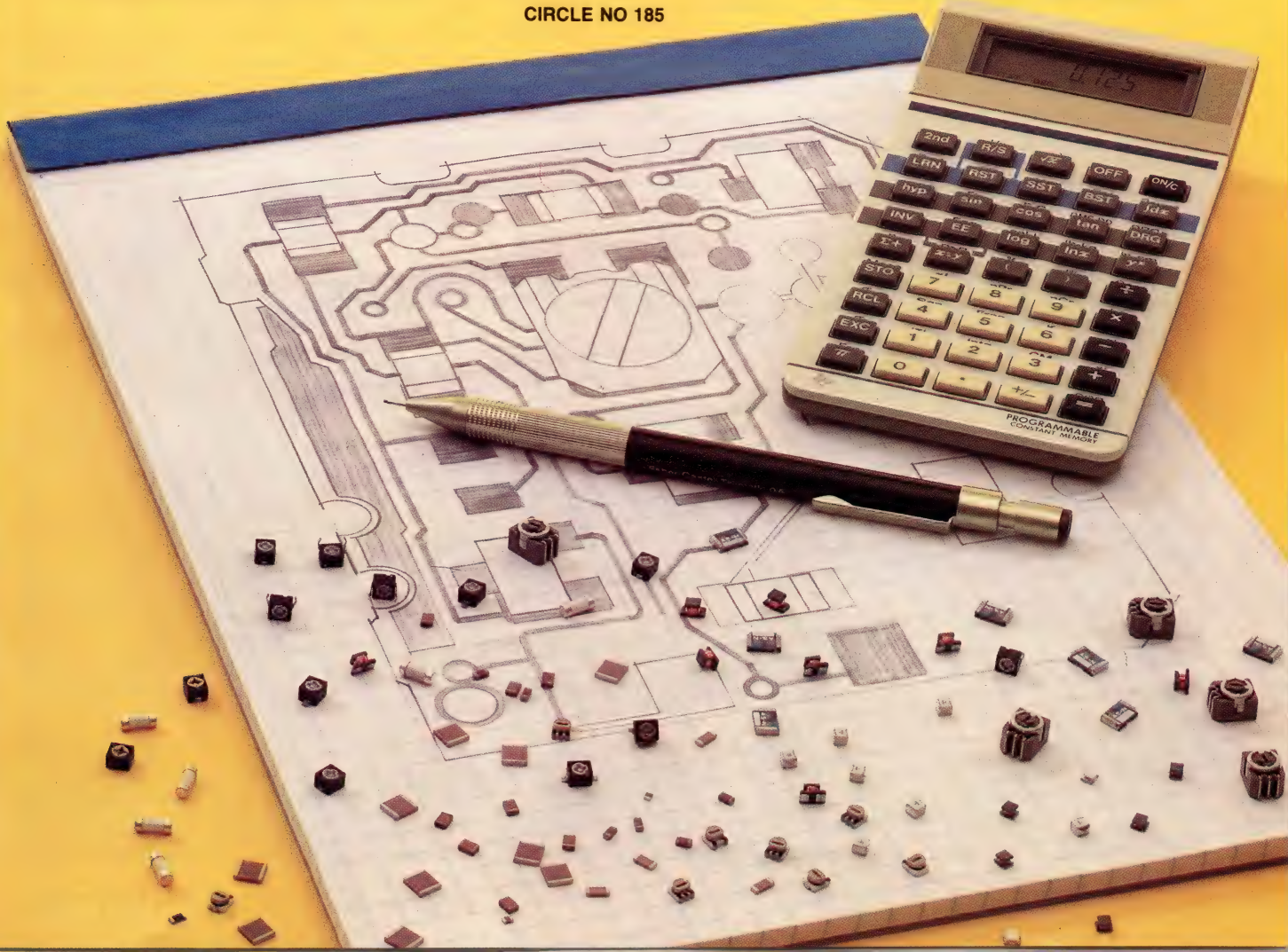
**Product synergism:** With a wide range of surface mounted configurations now available—ceramic capacitors, ceramic trimmer capacitors, fixed resistors, trimming potentiometers, inductors, ceramic resonators and ceramic filters—problems resulting from the integration of leaded and surface mounted devices have been significantly reduced.

To find out more about surface mounted components, write to Murata Erie North America, Inc., 2200 Lake Park Drive, Smyrna, GA 30080 or call 404-433-7878.



MURATA ERIE NORTH AMERICA, INC.

CIRCLE NO 185





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*Board-level thermal management has been a prime design consideration for many years, and SMT is increasing its importance.*

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the connectors for specific applications. For an application involving  $-55$  to  $+125^{\circ}\text{C}$  operation, for example, the connector would employ an alloy that triggers above  $125^{\circ}\text{C}$ .

## • Shielding

Given the complexity of today's electronic circuitry, electromagnetic compatibility is a critical design consideration. EMI and RFI can propagate along a conducting medium or radiate through space. In either case, the electromagnetic energy can cause undesirable interference and degrade the operation of a receiving system.

The FCC has established limitations on radiated and conducted interference levels for all computer and peripheral devices according to the class of product. Class A devices include those found in commercial, industrial, or business applications. FCC Docket No 20780 states that, depending on frequency, emanations from a Class A device shall not exceed specific field-strength levels at 30 meters. Over frequency ranges of 30 to 88, 88 to 216, and 216 to 1000 MHz, the field-strength limitations are 30, 50, and  $70\text{ }\mu\text{V/m}$ , respectively.

Although the FCC specifies maximum permissible interference levels from a system, the commission does

not tell enclosure manufacturers or system designers how to reduce emissions, and a battle is raging over how best to minimize radiation problems. Some see metal enclosures as the ideal solution for reducing EMI/RFI problems, though manufacturers of molded plastic enclosures contend that their products can provide acceptable electromagnetic compatibility.

The ideal EMI/RFI enclosure is a box (of metal or conductively coated plastic) without any seams or openings. Realistically, an effective cabinet is one that approaches these ideal qualities and provides access to internal components. The seams around all access points are crucial for maintaining good EMI/RFI integrity. The mating surfaces of all seams must be electrically connected, so you must use gaskets that feature high surface conductivity as well as good shielding properties. If different conductive materials are involved, they must be galvanically compatible to prevent a buildup of corrosion that can degrade gasket performance.

Instrument Specialties offers an extensive line of beryllium copper shielding strips for gasketing enclosure seams and openings. Beryllium copper does not absorb moisture or support fungus growth, and it isn't bothered by severe weather. It has excellent thermal

## For more information . . .

For more information on the material and hardware products discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or contact the following manufacturers directly.

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Minneapolis, MN 55435  
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*Product introductions indicate that connector manufacturers are striving to help designers cope with production problems.*

---

and electrical conductivity properties; it does not set under compression; and it is not affected by ozone, ultraviolet or nuclear radiation, EMP, or solvents.

The company's latest introduction is the Snap-tite clip-on shielding strip. The strips feature high holding power coupled with high electrical conductivity. They are well suited for high-vibration applications or situations where the available spring pressure cannot keep a gasket mounted securely. D-shaped lances clip into predrilled or prepunched holes, locking the gasket in place. Because Snap-tite gaskets require no friction for adherence, they are compatible with any type of surface. The strips come with various corrosion-resistant and high-conductivity plated finishes in standard or custom lengths.

Rather than implementing shielding yourself, you can buy enclosures that are already shielded. Manufacturers of plastic molded enclosures currently use two methods to control EMI/RFI. Most offer enclosures that are shielded with a conductive paint, a technique that's quite effective. Depending on the quantity of product involved, however, it can be an expensive solution. Amerex uses a second approach to shield its Unibox line of plastic enclosures. The company employs a family of die-cut Mylar and foil-laminated inserts, which slip into standard enclosures. These board shields are available in small quantities, and you can easily modify them to fit specific applications.

Conductive plastic materials hold great promise for shielding, but currently available materials cannot meet the cosmetic requirements of many applications. Material manufacturers are making progress in this area, however.

Meanwhile, Emcor has a line of metal enclosures that provide a good combination of shielding and accessibility. Designed to both contain and exclude radiated interference by reflecting and absorbing incident electromagnetic radiation, the enclosures feature a cabinet frame with 14-gauge, 1.75-in.-wide multiformed corner channels that are fully welded.

These frames support a static load of more than 3500 lbs without failing or permanently deflecting. The rugged construction is necessary to obtain and maintain the close-tolerance access openings required for proper EMI/RFI gasket sealing. The frames, along with all optional bolt-on components, are zinc-plated per MIL SPEC QQ-Z-325, Type II, Class 3. A highly conductive, galvanically compatible wire-mesh gasket, in combination with the optional components, provides EMI/RFI shielding around all openings.

The enclosures come in different styles and sizes. Both vertical and slope-front frames are available in 19- and 24-in. widths with depths of 25 $\frac{5}{16}$  and 31 $\frac{1}{16}$  in. The vertical frames come in 40 sizes, each in five different configurations. The slope-front units are available in eight sizes, each in four configurations. All emission-control side panels are removable from the inside and flush-mount within the frame's side channels. Top and closure panels are constructed of 16-gauge, cold-rolled steel. All can accommodate adhesive-backed, foam-wire-mesh gasketing.

#### **Shielding at the board level**

You don't have to wait until you get to the enclosure level to address magnetic interference problems. Bomco's M $\mu$ Shield material can prevent interference problems at the component level by diverting magnetic flux around sensitive circuitry. M $\mu$ Shield's permeability figures range from 200 to 350,000 (relative to the free-space permeability rating of 1).

Shielding applications fall into two categories: those where the shield must prevent fields from radiating, and those where the shield serves to prevent magnetic-field penetration. Bomco stocks three general types of M $\mu$ Shield material—high permeability, medium permeability, and high saturation—each of which can handle either application category.

High-permeability M $\mu$ Shield material has a minimum permeability of 80,000. Maximum permeability equals 350,000, and the saturation point is approximately 7500 gauss after treatment. Medium M $\mu$ Shield material is normally used in conjunction with high-permeability material. It has a permeability of 12,500 to 150,000 with a saturation point of approximately 15,500 gauss. Permeability for high-saturation material ranges from 200 to 50,000 with saturation points of 18,000 to 21,000 gauss.

Bomco heat-treats all M $\mu$ Shield material during manufacturing to ensure maximum permeability and low shock sensitivity. Should your shielding needs ever change, you can return the M $\mu$ Shield product for special heat treating. In addition, if you'd prefer to design your own shields, Bomco provides M $\mu$ Shield material in coil, sheet, and tubing form.

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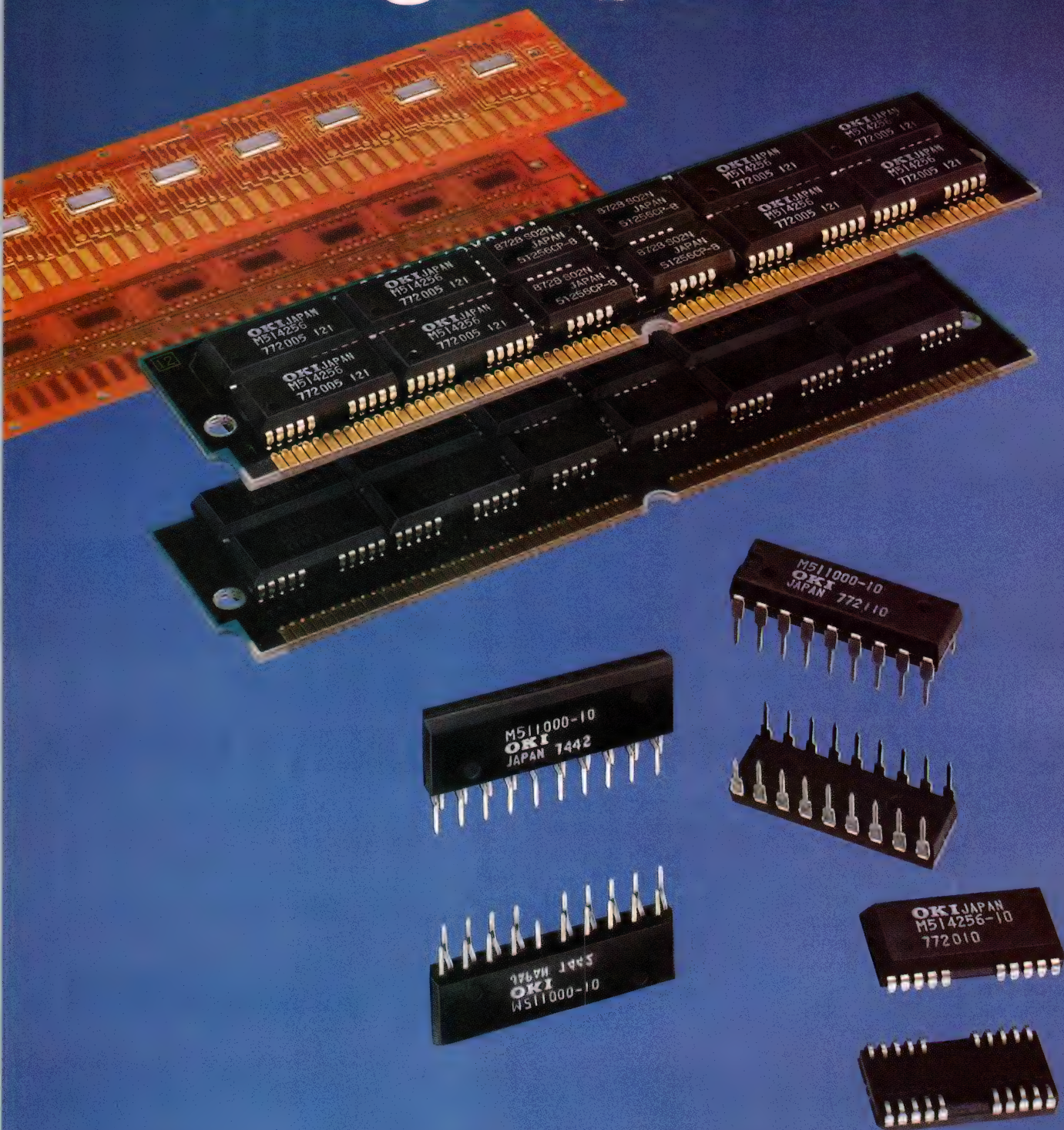
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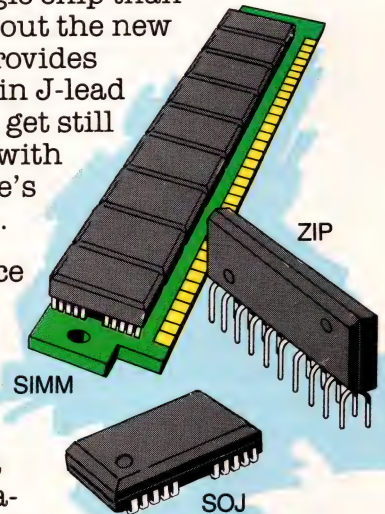


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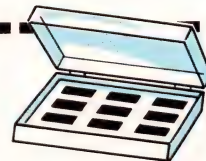


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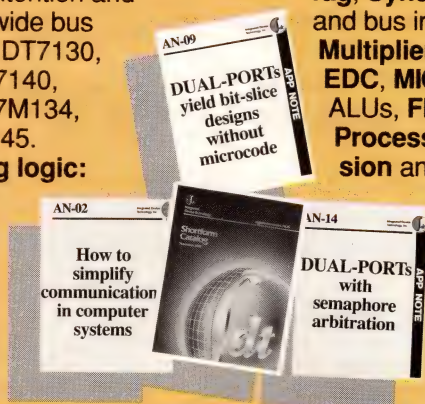
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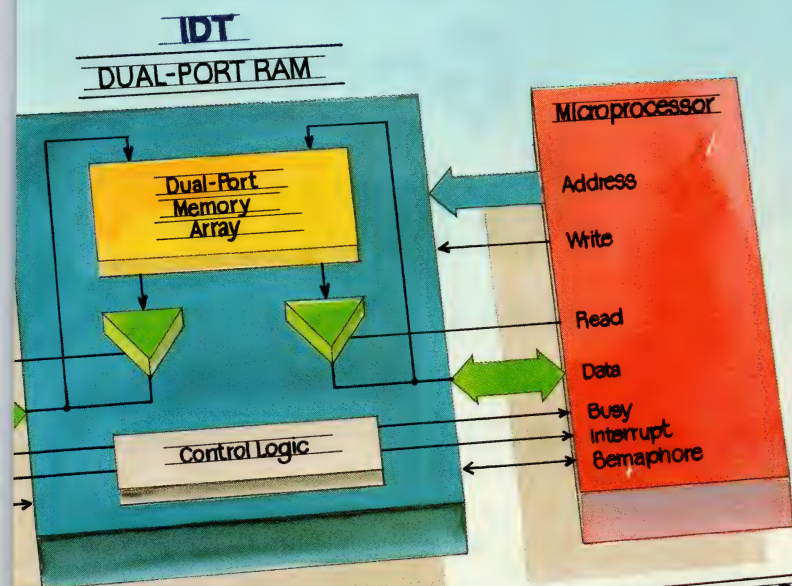
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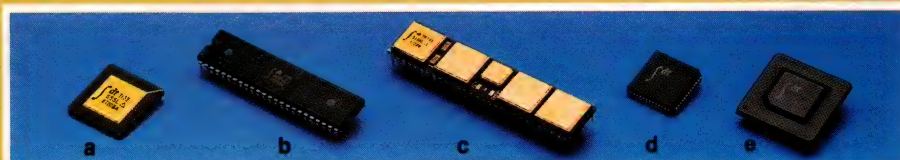
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## DUAL-PORT SELECTION GUIDE

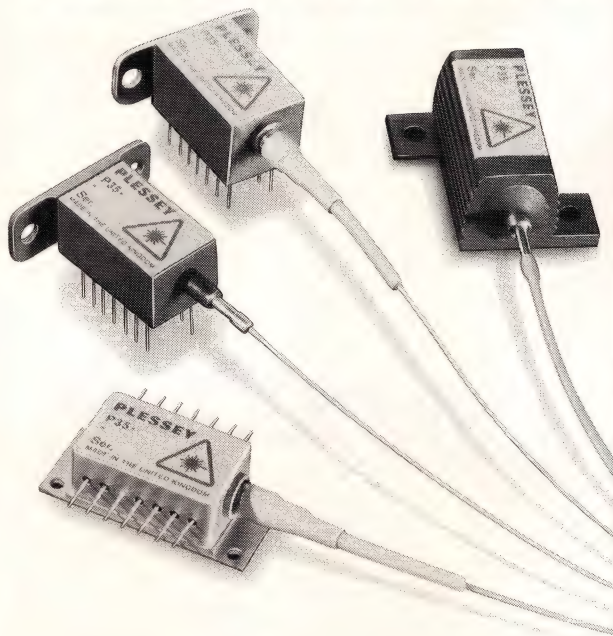
Description	Part Number	Access Time	Expandability	CONTROL LOGIC			
				Interrupt	Busy Logic		Semaphores
1Kx8	IDT 7130	35 ns	✓	x	MASTER	SLAVE	
"	IDT 7140	35 ns	✓	x	MASTER	SLAVE	
2Kx8	IDT 7132	35 ns	✓		MASTER	SLAVE	
"	IDT 7142	35 ns	✓	x	MASTER	SLAVE	
"	IDT 71321	35 ns	✓		MASTER	SLAVE	x
"	IDT 71421	35 ns	✓		MASTER	SLAVE	
"	IDT 71322	45 ns	✓		MASTER	SLAVE	
2Kx16	IDT 7133	55 ns	✓				x
"	IDT 7143	45 ns	✓				
4Kx8	IDT 7134	45 ns	✓				
"	IDT 71342	45 ns	✓				
8Kx8 Module	IDT 7M134	50 ns	✓		MASTER	SLAVE	
"	IDT 7M144	50 ns	✓		MASTER	SLAVE	
16Kx8 Module	IDT 7M135	50 ns	✓				
"	IDT 7M145	50 ns	✓				
32Kx8 Module	IDT 7M137	60 ns	✓				

- (a) Hermetic LCC  
(b) Plastic and hermetic DIP  
(c) Standard and custom modules  
(d) Plastic PLCC  
(e) Plastic and hermetic PGA





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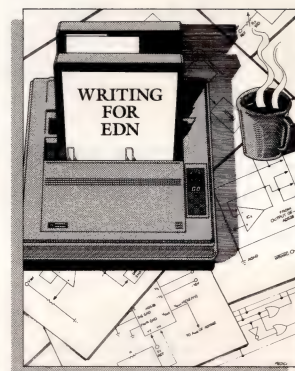
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# Programmable array serves as a controller for dynamic RAMs

---

*Large memory systems that use dynamic RAMs often have varying requirements for control. A programmable gate array can offer the flexibility to meet the needs of various memory-system applications. In addition to integrating refresh circuitry, it contains sufficient logic to allow you to implement error detection and correction.*

---

Thomas Waugh, Xilinx Inc

To produce cost-effective products with large amounts of memory, designers often prefer to use low-cost, high-density dynamic RAMs instead of the comparatively more expensive and less dense static RAMs. However, dynamic RAMs require control circuitry that static RAMs don't. To implement that circuitry in a single chip, you can use a programmable gate array. Such a device can provide refresh signals (the capacitor that makes up each dynamic memory cell must be recharged, or refreshed, typically once every two to four milliseconds), and it can provide the error detection and correction that can alleviate the headaches that the dynamic RAMs' susceptibility to soft errors can cause (see **box**, "Soft errors can cause hard problems").

You'll find several options available to you for dynamic-RAM controller designs. The simplest option is an

off-the-shelf standard LSI memory controller. The manufacturers of these parts combine  $\mu$ P interface logic with memory-access and memory-refresh circuitry on one chip. However, each memory system has unique timing and protocol requirements, so standard parts can't accommodate every system. Even though some manufacturers include some degree of programmability in their parts, designers must often employ glue logic, in the form of extra SSI or MSI packages, to meet system requirements.

Custom gate arrays provide a highly integrated solution. However, nonrecurring engineering costs, testing and simulation costs, inventory risk, and the long design cycle make the custom gate array unattractive for many designs.

The Logic Cell Array (LCA) device can overcome some of these difficulties. Its programmability gives the designer freedom to tailor the dynamic-RAM controller to the exact specifications of a memory system without external glue logic (see **box**, "LCA devices offer flexibility"). You can configure the LCAs to meet unique system requirements without the loss in integration posed by the SSI/MSI solution and without the costs and risks associated with the custom gate-array solution.

The 2000-gate XC3020 LCA device is well suited for designing a dynamic-RAM controller. Not only does a single XC3020 incorporate dynamic-RAM control functions and error detection and correction, but the CMOS device also consumes less power than standard programmable controllers, which are typically imple-

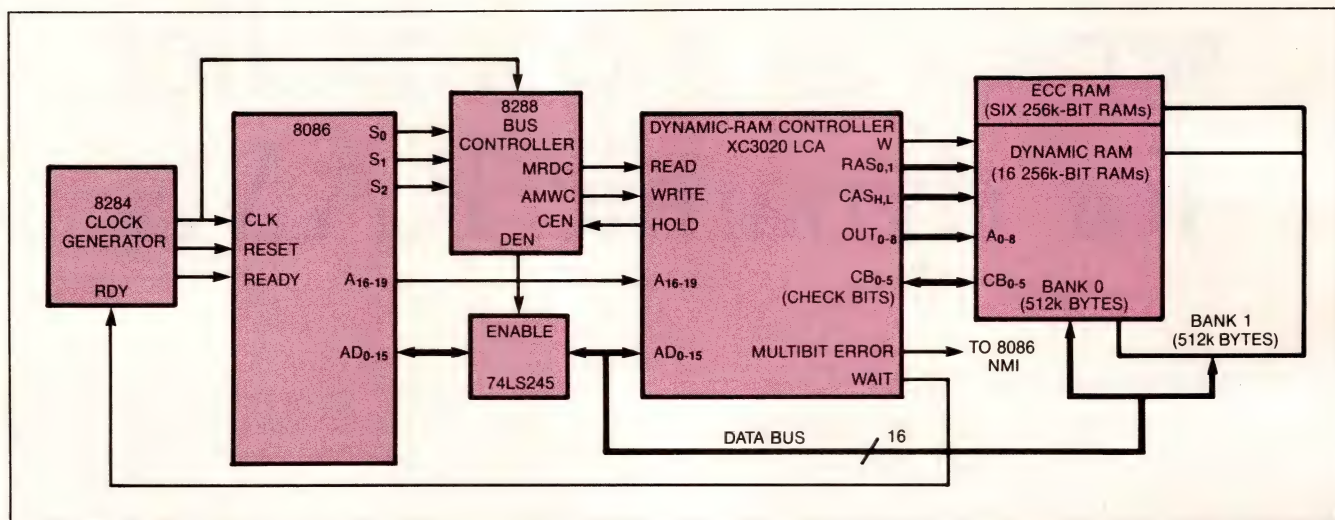


## *A nuisance associated with dynamic RAMs is their susceptibility to soft errors.*

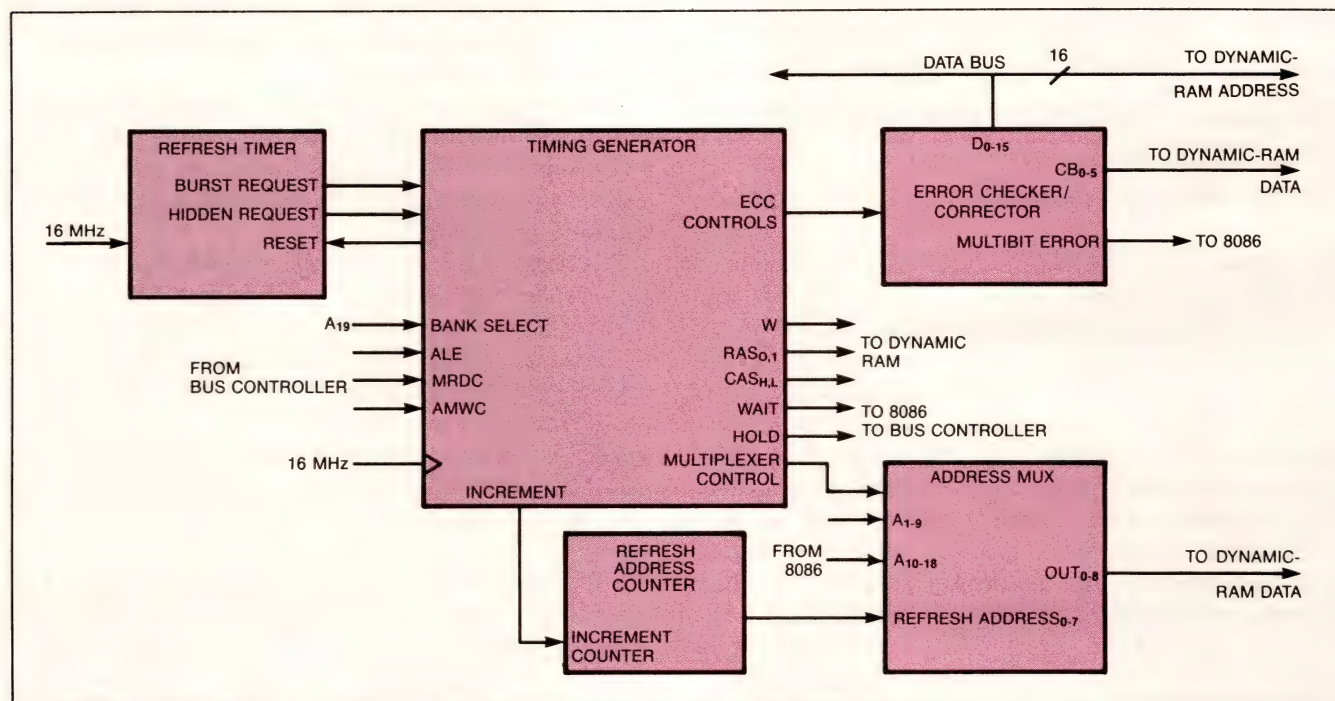
mented in NMOS or bipolar technologies.

Consider a design example based on an 8-MHz 8086  $\mu$ P that directly addresses 1M bytes of memory made up of 32 256k-bit dynamic-RAM chips. A single LCA serves both as a dynamic-RAM controller and an error checker/corrector (ECC). The dynamic-RAM controller uses a 16-MHz clock synchronized to the  $\mu$ P's clock and

resides between the 8086  $\mu$ P (along with its 8288 bus controller) and the system memory (Fig 1). Two '245-type octal bus transceivers determine the communication direction (that is, whether the 8086 will read from or write to the dynamic RAM). The 8288 bus controller supervises the transceivers and can isolate the  $\mu$ P from the dynamic-RAM data bus by placing the transceivers



**Fig 1—The 2000 logic gates in an XC3020 allow it to incorporate control and error-correction and -detection circuitry for an 8086-based system.**



**Fig 2—You can view the dynamic-RAM controller as consisting of the five basic blocks shown here.**



in a high-impedance condition via the enable (EN) command.

The 8288 bus controller also decodes the  $\mu$ P status lines ( $S_2$ ,  $S_1$ , and  $S_0$ ) and informs the dynamic-RAM controller whether it should perform a read or write operation. The dynamic-RAM controller then performs the appropriate operation, issuing a row-access strobe (RAS), a column-access strobe (CAS), and a write (W) signal, if necessary. The controller generates error-correction bits on each write operation, and it checks and corrects errors on each read operation. The controller also informs the  $\mu$ P if a memory access requires a wait state or if the controller has detected an error that it can't correct.

Fig 2 is a block diagram of the dynamic-RAM controller and error checker/corrector that reside in the LCA. The refresh timer uses a 16-MHz clock to furnish a signal that informs the dynamic-RAM controller when to refresh the memory. Each of the 256 rows of memory in this system needs refreshing every 4 msec. The refreshing technique employed provides a combination of hidden and burst refreshes. The controller refreshes eight rows every 125  $\mu$ sec, which corresponds to 4 msec  $\div$  125  $\mu$ sec = 32 sets of eight refreshes during the

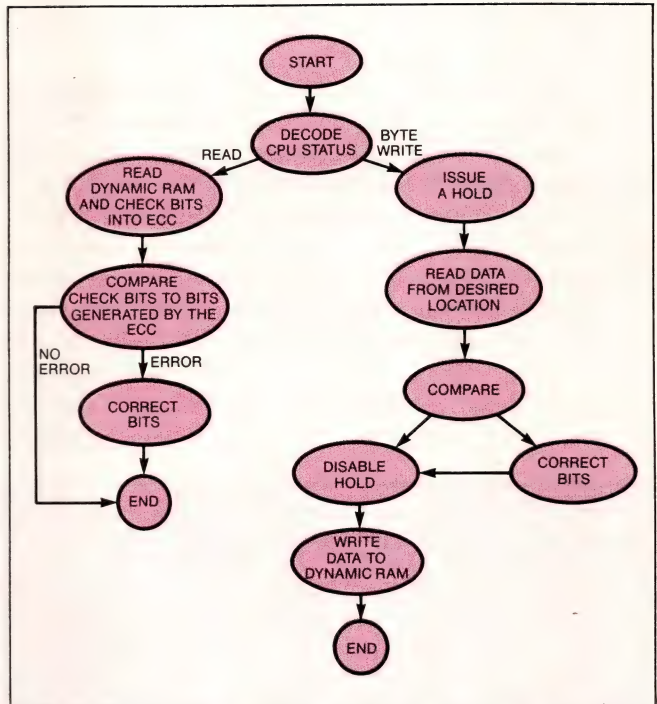


Fig 3—The modified Hamming code that the error checker/detector in Fig 2 uses conforms to this state diagram.

## Soft errors can cause hard problems

Dynamic RAMs are much more susceptible to soft errors than static RAMs are. A soft error is the loss of data in a memory cell that is not permanently damaged. Rewriting the data in the cell corrects the error. This type of error is different from a hard error, which results when a memory cell is permanently damaged.

Usually alpha particles (helium nuclei) cause soft errors in dynamic RAMs. Alpha particles are normally present in the atmosphere, but the ones responsible for most soft errors are emitted by radioactive impurities in the IC package of the dynamic RAMs themselves. If an alpha particle hits a memory

cell, it can corrupt the cell's charge, causing a data-bit error.

Many people are under the impression that the likelihood of such an error is so slight that it can be safely ignored. Although this belief might have been true for the smaller memory systems of the past, it is no longer so. The size of memory systems today makes soft errors unacceptably likely.

A typical error rate for NMOS dynamic RAMs is about 0.12% per 1000 hours, which translates to an MTBF (mean time between failures) of 1000 hours/0.0012 = 833,333 hours, or a little over 95 years. However, this spec is for only one RAM chip. The original IBM PC had 64k

bytes of RAM, comprising thirty-six 16k-bit dynamic RAMs. The MTBF of such a memory is about 833,333 hours/36 dynamic RAMs = 23,148 hours, or just over 2½ years. This value is still probably acceptable. However, the 16M-byte memories in common use today comprise 512 25k-byte dynamic RAMs and have an MTBF of less than 10 weeks. This value is too low for many applications. Device and packaging improvements can reduce the probability of a soft error. However, the most effective means of minimizing such errors is to incorporate error detection and correction into the dynamic-RAM controller.



*During a write cycle, the ECC circuitry generates six check bits, using a modified Hamming code, for a 16-bit data word.*

specified refresh period (that is,  $32 \times 8 = 256$  row refreshes every 4 msec).

The timing generator is a state machine triggered by the Address Latch Enable (ALE) command from the  $\mu P$  at the beginning of the processor cycle. The timing generator generates all the timing signals required to perform the memory accesses and refreshes. Its address multiplexer selects which address is sent to the dynamic RAM. During a read or a write operation, the multiplexer control signal from the timing generator selects a row address from the  $\mu P$  and strobes it with the RAS line. Then, the address multiplexer selects a column address from the  $\mu P$  and strobes it into the dynamic RAM with the CAS line. During a refresh

operation, a refresh address counter generates an 8-bit address, which is selected by the address multiplexer. The RAS line strobes the refresh address into the dynamic RAM.

During a write cycle the ECC circuitry generates six check bits, using a modified Hamming code, for a 16-bit data word. The standard Hamming code requires five bits to provide single-bit error detection and correction. The added sixth bit (which is used for a parity check of the data and five check bits) allows the modified Hamming code to provide single-bit error correction and double-bit error detection. Fig 3 shows a state diagram for the ECC circuit.

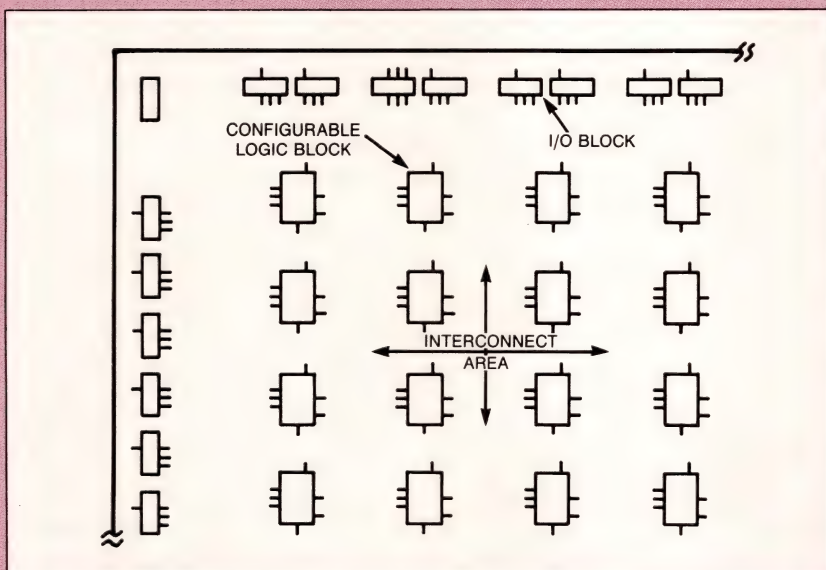
During a read cycle, the ECC circuitry generates a

## LCA devices offer flexibility

Devices such as the XC3020 Logic Cell Array, available from Xilinx (San Jose, CA), have user-programmable architectures, and consist of three types of configurable elements on a chip: a perimeter of I/O blocks (IOBs), a core array of configurable logic blocks (CLBs), and resources for interconnection.

The general structure of an

LCA is shown in Fig A. The perimeter of configurable IOBs provides a programmable interface between the internal logic array and the device package's pins. The array of CLBs performs user-specified logic functions. The interconnect resources—which are analogous to pc-board traces—carry logic signals among the blocks.



**Fig A—**An LCA device consists of an array of interconnected logic blocks surrounded on the periphery by I/O blocks.

A configuration program stored in internal static memory cells determines the user-defined logic functions and interconnections. The program is loaded when the power is turned on or when a program mode is enabled. The program data resides externally in an EEPROM, EPROM, ROM, or on a floppy or hard disk. The configuration is determined by an XACT development system, which operates in an IBM PC/AT or compatible with 640k bytes of internal RAM, 1.5M bytes of extended memory, color graphics, a mouse, and DOS 3.0 or higher. The development system provides interactive design and editing along with logic and timing simulation.

The XC3020 has 2000 usable gates for logic functions. The internal static memory has a capacity for as many as 14,815 data bits, which control 64 configurable logic blocks and 58 I/O blocks. In addition, 3-state internal buses facilitate wide wire-AND functions.



new set of check bits from the data that's read from memory. The ECC circuitry compares these check bits with the check bits that were stored in memory to see if an error has occurred. If the comparison yields a correctable error, the ECC circuitry corrects it. When it detects a noncorrectable double-bit error, the ECC circuitry flags the  $\mu$ P.

### Memory cycles' timing requirements vary

The timing requirements for different memory cycles are shown in Fig 4. Fig 4a shows a memory cycle that requires that a word be written to memory with no wait states. After asserting a row and column address and strobing the dynamic RAM with the respective RAS and CAS lines, the controller asserts the W line to write the 16-bit data word and the six generated check bits to the dynamic RAM.

A memory cycle that requires that a single byte be written to memory is more complicated (Fig 4b). First, the controller must read the word resident in the desired memory location and check it for errors. Then the controller inserts the new byte into the appropriate byte of the word. The ECC circuit generates a new set of check bits, and the newly formed combination of word and check bits is written to memory when the controller asserts the W line. This operation involves inserting two wait states and isolating the controller from the  $\mu$ P data bus to perform the read from memory. The controller issues a Hold command to the 8288 bus controller, which disables the '245 transceiver to isolate the controller from the data bus. Fig 5 shows a state diagram for the Hold and Wait logic circuitry.

Memory cycles that require a read from memory are shown in Fig 4c and Fig 4d. A read operation requires a minimum of one wait state—the penalty for implementing error correction and detection. The insertion of a wait state is unavoidable because of the time required to detect an error. If the ECC circuitry detects an error, two wait states must be inserted to allow time to correct the error. The corrected data along with the check bits are written back into memory when the controller asserts the W line.

A hidden refresh can occur when the  $\mu$ P is reading from or writing to some device other than memory, such as an I/O port. The address multiplexer selects a refresh address from the refresh address counter and applies it to the dynamic RAM. The timing generator issues an RAS command to execute the refresh.

A burst refresh (Fig 4e) occurs only if the refresh timer indicates that the required eight refreshes have

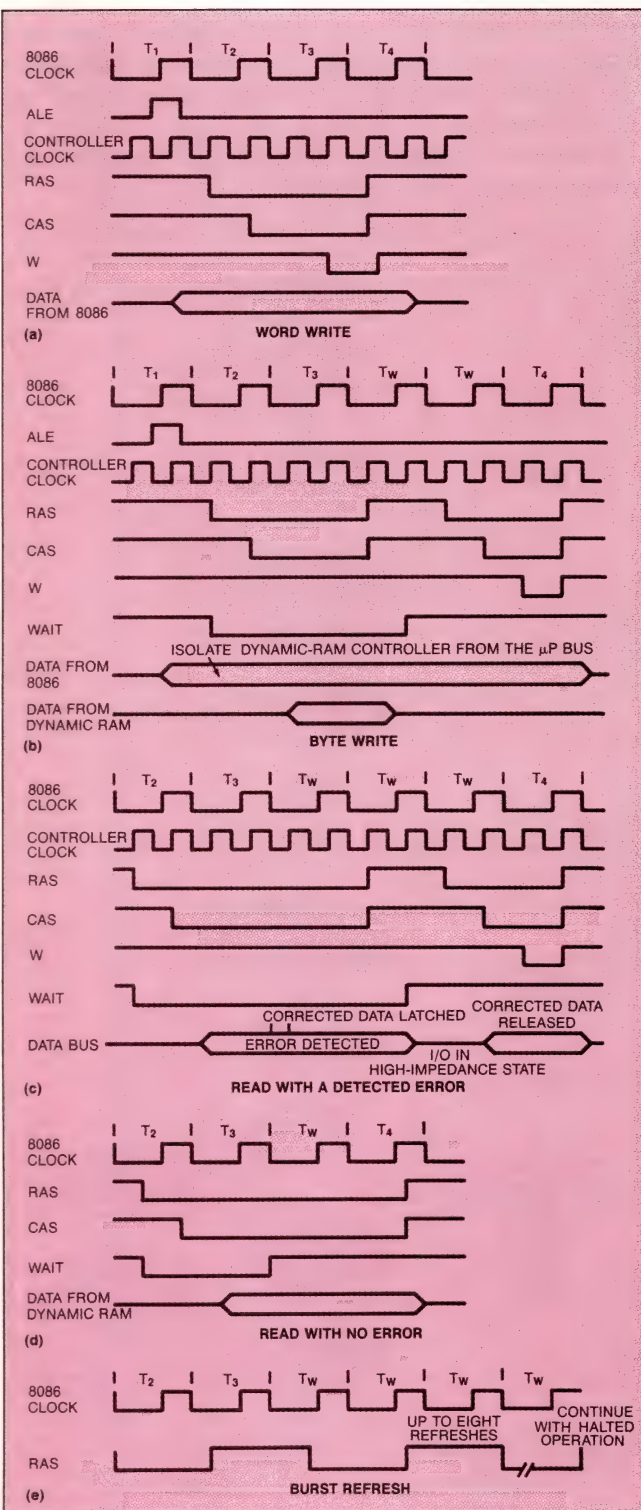
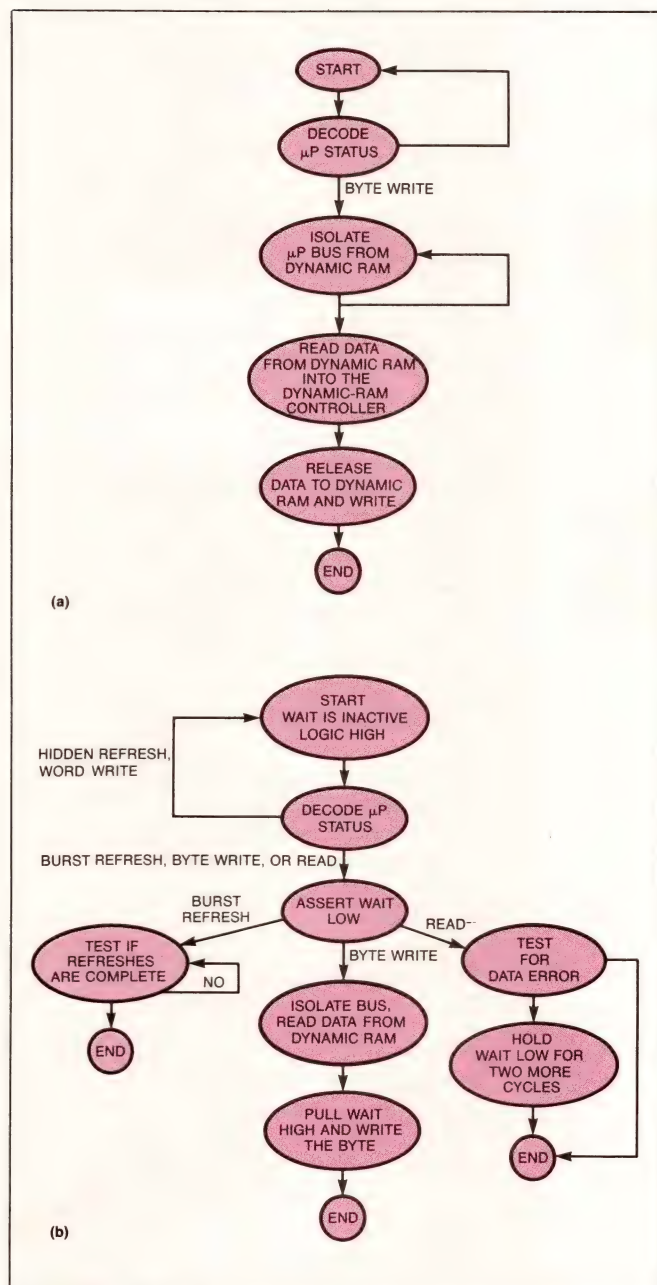


Fig 4—When performing the various read, write, or refresh operations, the controller's logic circuitry must provide the appropriate timing.



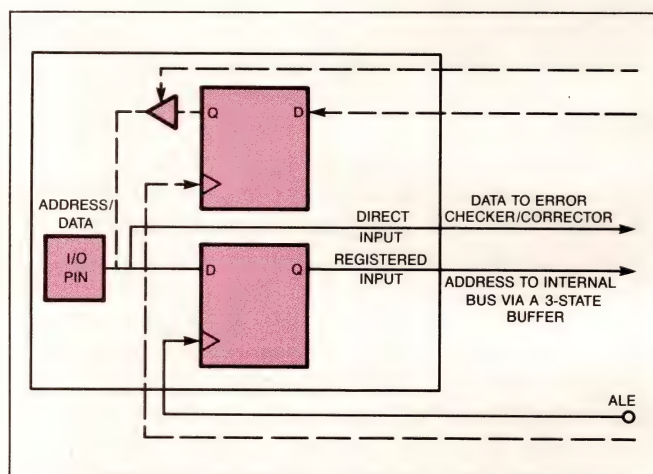
## The dynamic-RAM controller takes advantage of the internal buses on the LCA.

not taken place during a 125- $\mu$ sec refresh period. To execute the burst refresh, the controller must isolate the memory from the  $\mu$ P by issuing a Hold command, which disables the transceiver. The controller also inserts wait states and provides the number of refreshes required to complete the eight refreshes.

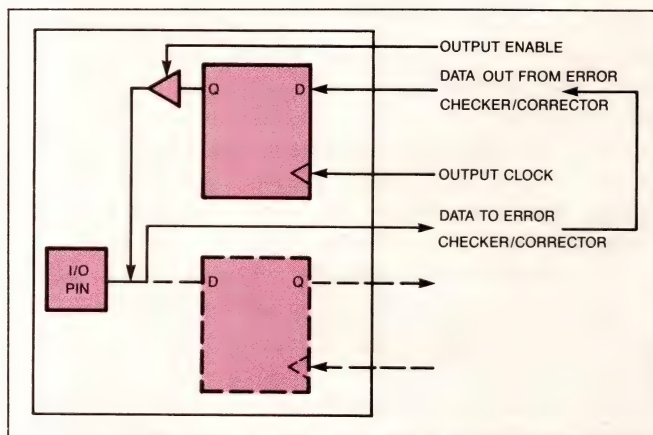


**Fig 5—The Hold state diagram (a) illustrates the isolation of the  $\mu$ P from the data bus. Memory cycles that require wait states follow the Wait state diagram (b).**

Some features of the 3000 family LCA architecture aid the design of the dynamic-RAM controller. **Fig 6** shows a bit-sliced view of one of the address and data IOBs (input/output blocks) located inside the LCA. The IOB provides two paths to the CLBs (configurable logic blocks) on the chip. One is direct and the other is through a storage element, which you can configure as an edge-sensitive flip-flop or as a level-sensitive transparent latch. This circuit arrangement lets you latch addresses and data on a multiplexed bus, such as that used by an 8086  $\mu$ P, into the LCA device. The ALE command from the 8086 latches the addresses into the dynamic-RAM controller. Data from the  $\mu$ P enters the same input pin and goes directly to the ECC circuit through the IOB's direct path. No external latches are necessary.



**Fig 6—Data at an I/O pin on the XC3020 can be either latched into the device or passed directly to a CLB.**



**Fig 7—The dynamic-RAM controller makes use of the 3-state buffers placed on the XC3020's output registers.**



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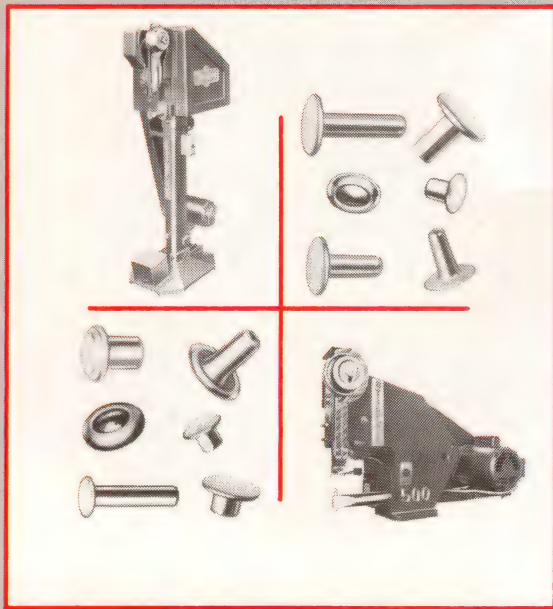
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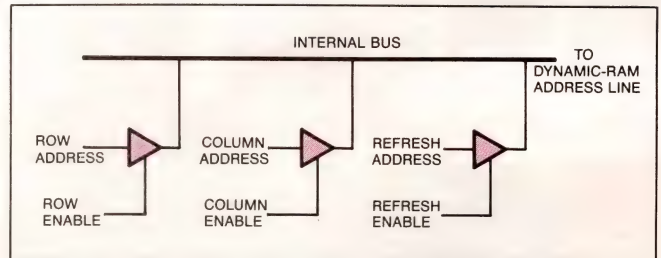


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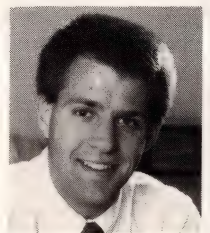
**Fig 8—The 3-state drivers** attached to the internal bus on the XC3020 allow the multiplexing of addresses onto one line.

The ECC circuit in the dynamic-RAM controller utilizes the 3-state buffer placed on the outputs of the output register of an IOB (Fig 7). During a memory-read cycle, for example, the controller puts the IOB output in a high-impedance condition, thereby allowing dynamic-RAM data on the data bus to enter the ECC circuit via the direct input path. If the ECC detects a data-bit error, it will correct the error and latch the corrected data word into the output register of the IOBs. The controller forces the dynamic-RAM outputs to a high-impedance condition and releases the corrected data onto the data bus by enabling the 3-state output buffer. The corrected data is then read by the 8086  $\mu$ P and written back to the dynamic RAM simultaneously.

The dynamic-RAM controller also takes advantage of the internal buses on the LCA device. Because the drivers to the horizontal bus can be placed in high-impedance conditions, all of the row addresses, column addresses, and refresh addresses are multiplexed onto the same bus (Fig 8). The dynamic RAMs have access to this bus when the data is latched into the output registers of the IOBs. Enabling the correct 3-state bus drivers forces the proper sequence of addresses. **EDN**

## Author's biography

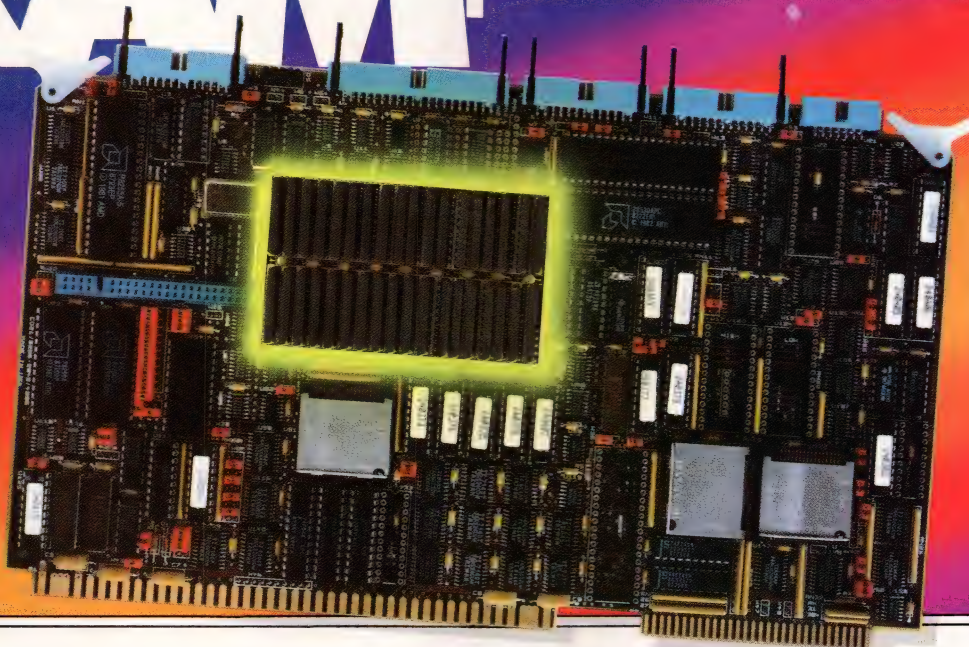
Thomas Waugh is an applications engineer with Xilinx Inc (San Jose, CA). His duties include application design and technical support. He previously worked at Johns Hopkins University's Applied Physics Lab. He received a BSEE degree from Stanford University and is a member of the IEEE. In his spare time he enjoys reading, swimming, and traveling.



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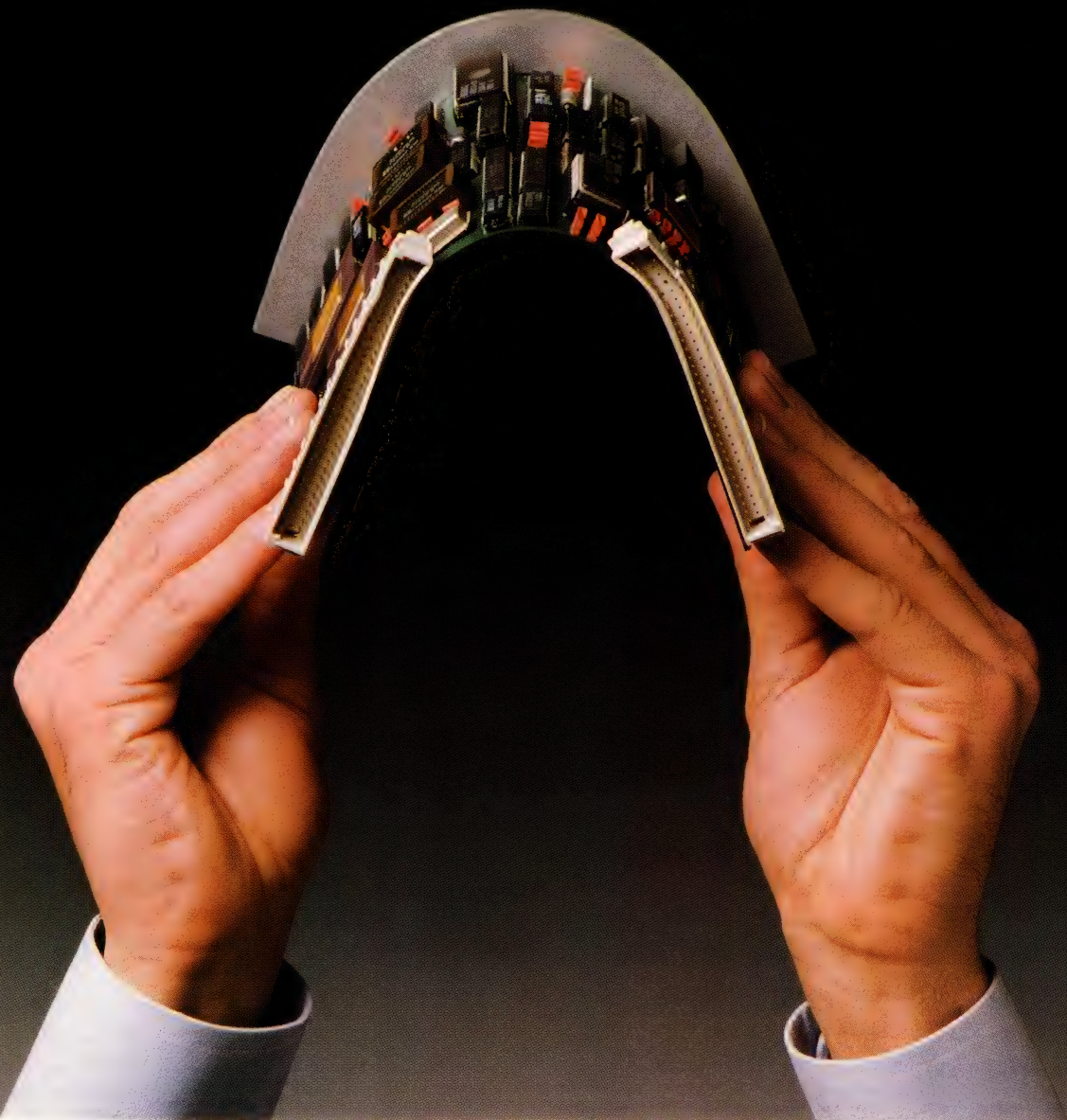
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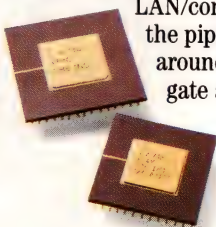
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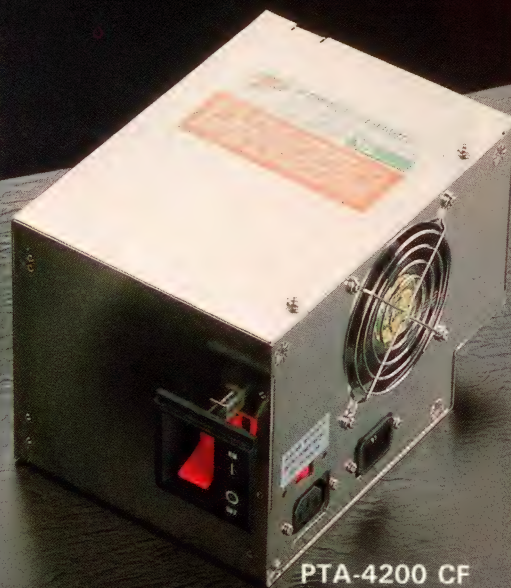


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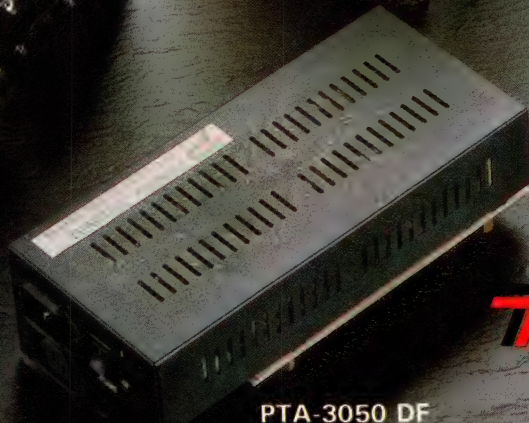
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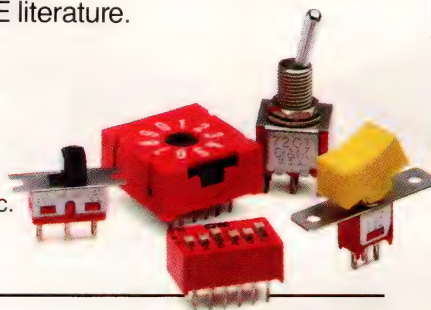
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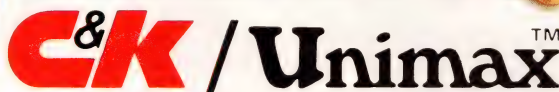
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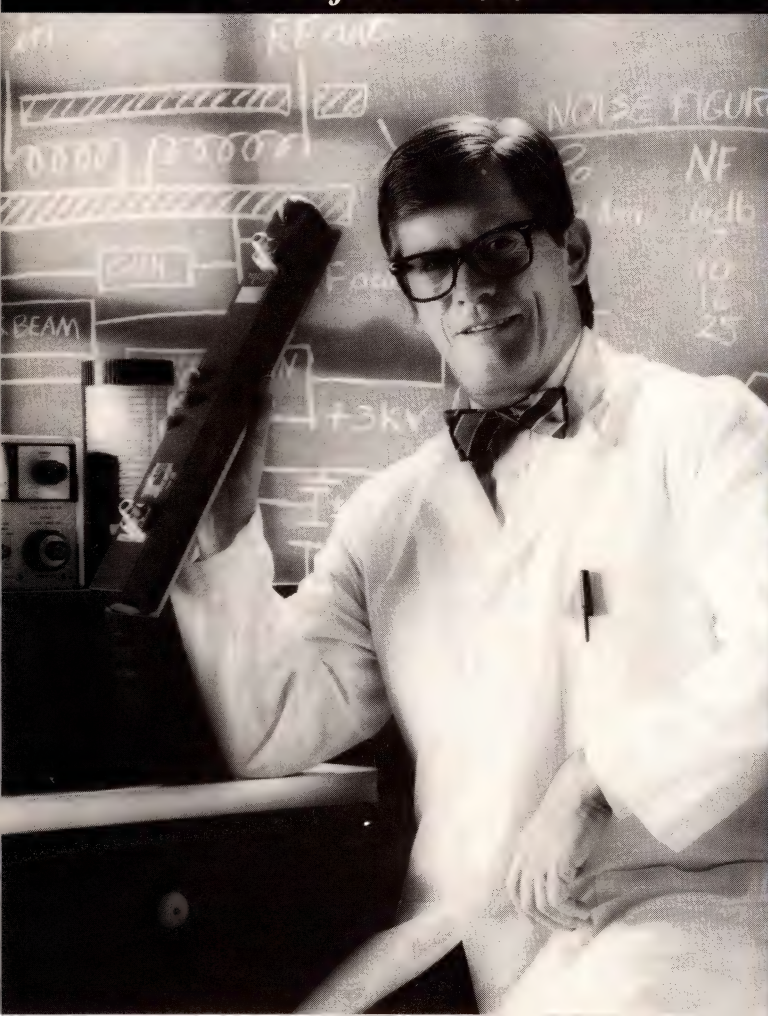
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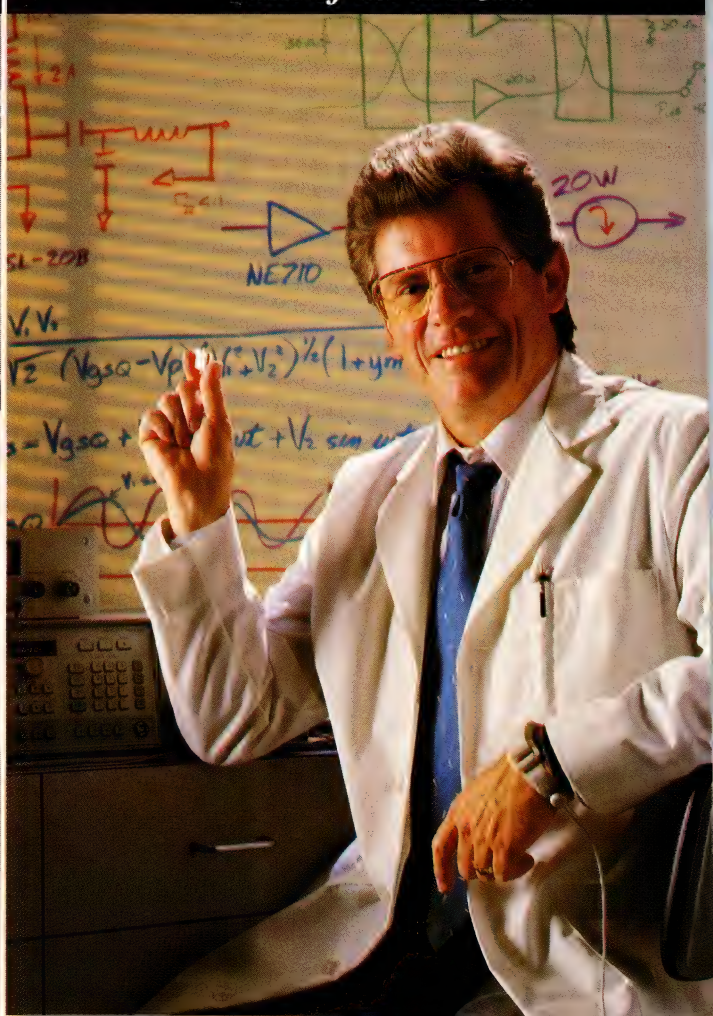
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# Selection criteria assist in choice of optimum reference

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In choosing a precision voltage reference, you should look beyond initial accuracy, temperature coefficient (TC), and cost. Other factors that determine the suitability of a reference for your application are the device's power dissipation, noise, long-term stability, package size, ease of use, TC linearity, and the manufacturer's definition of TC. Familiarity with these selection criteria will help you avoid unpleasant surprises when you characterize your prototype system.

Before going into the details of the various selection factors, it's useful to briefly review the different types of references available and to explain the principles of operation of each type. The overview will give you some insight concerning the performance you can expect from the various references. Reference circuits com-

prise three categories: bandgap cells, zener-diode-based references, and heated-substrate types. Most voltage references fall into the first two categories and derive their fixed output from a bandgap cell or a zener diode. The third type of reference obtains additional stability by mounting the bandgap or zener circuit on a heated substrate.

Bandgap references depend on the behavior of diodes (or the equivalent base-emitter junctions of transistors). The following equation predicts the operation of such junctions with a high degree of precision.

$$V_{BE} = V_{G0} \left( 1 - \frac{T}{T_0} \right) + V_{BE0} \left( \frac{T}{T_0} \right) + \frac{nkT}{q} \ln \left( \frac{T_0}{T} \right) + \frac{kT}{q} \ln \left( \frac{I_C}{I_{C0}} \right),$$

where

- $V_{G0}$  = the extrapolated bandgap voltage (about 1.2V) at 0°K
- $n$  = process-dependent constant; value 1.5 to 3
- $q$  = charge of an electron
- $k$  = Boltzmann's constant
- $T$  = temperature in °K
- $I_C$  = collector current
- $T_0$  = reference temperature for  $V_{BE0}$  and  $I_{C0}$
- $I_{C0}$  = reverse saturation current at  $T_0$
- $V_{BE0} = V_{BE}$  value for the conditions  $T_0$  and  $I_{C0}$ .

The diode's temperature coefficient is large but predictable and repeatable ( $-2$  mV/°C or  $-3100$  ppm/°C). Thus, you can achieve stability by balancing the diode's



*The  $V_{BE}$  equation's third and fourth nonlinear terms limit the performance of bandgap references by making a flat voltage/temperature response impossible.*

TC with a TC of equal magnitude and opposite sign. Such a TC exists for the *difference* between the forward voltages of two diode junctions operating at different current densities. Because the ratio of mismatch governs the TC's value, the bandgap circuit is compatible with good IC design—parameter values should depend on accurate ratios based on layout geometry, rather than on absolute quantities that are difficult to control.

You can calculate the desired difference voltage ( $\Delta V_{BE}$ ) with high predictability, directly from the diode equation

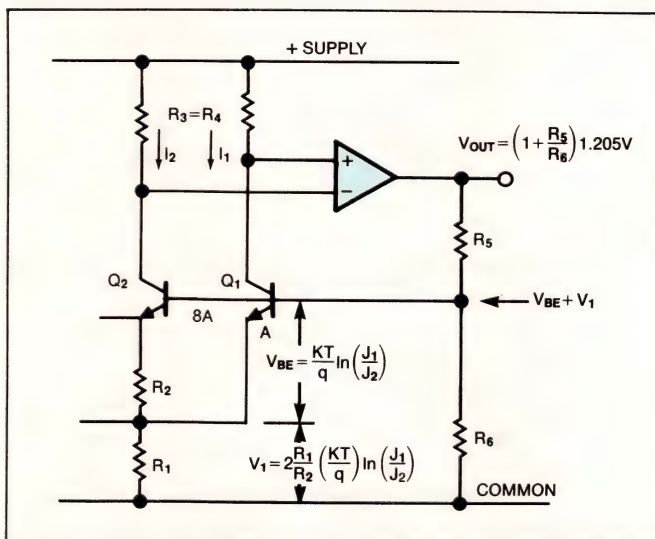
$$\Delta V_{BE} = \frac{kT}{q} \ln \left( \frac{J_1}{J_2} \right),$$

where  $J_1/J_2$  is the ratio of current densities. To obtain zero TC, you add the expression for  $V_{BE}$  to the one for  $\Delta V_{BE}$ , differentiate the sum with respect to temperature ( $T$ ), and set this quantity equal to zero. The result is

$$V_{G0} = V_{BE0} + \frac{kT}{q} \ln \left( \frac{J_1}{J_2} \right).$$

Solving this equation for the  $J_1/J_2$  ratio tells you that an approximate 8:1 ratio gives the best result (a near zero TC). Scaling the transistor areas gives an IC designer accurate control of this ratio.

In a basic bandgap circuit (Fig 1),  $V_{BE}$  is the base-



**Fig 1—A bandgap voltage reference** generates the sum ( $V_{BE} + V_1$ ), in which the two voltages have equal and opposite temperature coefficients. The amplifier then raises the sum to a more convenient voltage level.

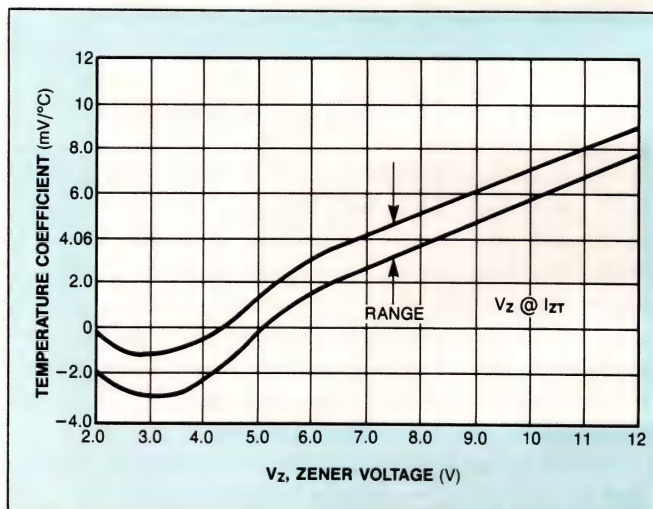
emitter voltage of  $Q_1$ , and  $\Delta V_{BE}$  appears across  $R_2$ . The ratio of  $R_1$  and  $R_2$  scale  $\Delta V_{BE}$  to a voltage ( $V_1$ ) whose TC cancels the TC of  $V_{BE}$ . The amplifier then raises the 1.2V sum of  $V_1$  and  $V_{BE}$  (the bandgap-cell voltage) to a higher level at  $V_{OUT}$ : usually 2.5 to 10V. Unfortunately, the amplifier multiplies noise as well. A 10V scaled output, for example, increases the bandgap cell's noise voltage by an approximate factor of 8 ( $10 \div 1.2$ ).

Commonly available bandgap-reference voltages are 10, 5, 2.5V, and the bandgap-cell voltage itself, 1.23V. Typical TCs range from 5 to 50 ppm/°C. The  $V_{BE}$  equation's higher-order, logarithmic third and fourth terms limit the performance of these references by making a flat voltage-temperature response impossible. What's more, some of the equation's coefficients are process-dependent—particularly  $n$ , which is related to the carrier mobility of dopant in the silicon. The quantity  $n$  poses a problem because you cannot easily determine its value by making electrical measurements during production.

Because most bandgap references are constructed in silicon monolithic form, they are relatively inexpensive (\$3 to \$20). Many designs employ curvature correction to compensate for the logarithmic nonlinearity in the TC, but none offer an exact cancellation.

### Zeners have rock-bottom TCs

The second type of voltage reference—based on a zener diode—achieves TCs as low as  $\pm 1$  ppm/°C. Zener diodes have a positive or negative TC, depending pri-



**Fig 2—Zener diodes produce a zero-TC voltage** near 5V—the level for which the mechanisms of negative-TC field-emission breakdown and positive-TC avalanche breakdown are in balance. However, the zero-TC ideal is difficult to achieve on a production basis.



marily on the breakdown-voltage value and to a lesser degree on the operating current. The zener breakdown involves two mechanisms: field-emission breakdown, which dominates below 5V and produces a negative TC, and avalanche breakdown, which occurs above 5V and yields a positive TC. Although complex and difficult to quantify, these breakdown mechanisms should be in balance at approximately 5V, yielding a near-zero TC. Tests corroborate this contention (Fig 2).

Unfortunately, 5V zener diodes exhibiting the utopian zero TC are difficult to produce. The problem is that the negative TC breakdown mechanism is fluky and difficult to reproduce consistently in production. The positive TC breakdown, on the other hand, is predictable and eminently repeatable for devices using routine semiconductor-production processes. Another charac-

teristic that's predictable and repeatable is the negative-slope temperature characteristic of a forward-biased diode.

Because of the difficulty of producing a zero-TC zener diode that depends purely on breakdown mechanisms, it's evident that the TC of a zener-diode reference should not depend solely on the absolute zener breakdown voltage. A class of zener diodes, called TC zeners, takes a compensatory approach by balancing the negative TC of a forward-biased diode ( $-2 \text{ mV}/^\circ\text{C}$ ) with the equal and opposite TC of a 5.6V zener diode. The output voltage is therefore 6.3V ( $0.7\text{V} + 5.6\text{V}$ ). These references offer 5- to 100-ppm/ $^\circ\text{C}$  TCs and require operating currents from 0.5 to 7.5 mA. You must maintain the specified operating current to obtain the guaranteed TC.

## Precision references need laser trimming

To achieve accuracies as tight as  $\pm 0.01\%$  in precision references, manufacturers use laser-trimmed thin-film resistors. Diffused resistors embedded within silicon exhibit not only hysteresis, but also high TC, poor TC matching, large voltage coefficients, and poor stability. Thin-film resistors, deposited on the chip's surface, are found in such voltage references as the REF01, AD581, AD2700, and the MAX670.

The secret to the precision references' accuracy is to trim

the thin-film resistors by laser before attaching a lid to the package. This critical operation determines a reference's initial accuracy and its long-term stability. Fuse-link blowing and resistor-link trimming are alternative schemes for trimming the absolute voltage, but the chip area required with these methods makes them prohibitively expensive for tight-tolerance adjustments.

Thick-film resistors have insufficient stability for use in precision references; therefore, hy-

brid products such as the MAX670, AD2700, and AD2710 include TaN (tantalum nitride) or NiCr (nichrome) thin-film resistors, sputtered on a ceramic substrate of 99.6% alumina ( $\text{Al}_2\text{O}_3$ ). Before trimming each lot of references, the manufacturer determines the optimum settings for laser power and focus by executing a test matrix of experimental laser cuts.

For each power setting, the system makes a staircase trim pattern in which each right-angle turn marks an additional increment of focus (Fig A). After completion of the focusing and system-calibration steps, quality-control personnel inspect the trim process every 30 minutes to ensure uniform cuts throughout the manufacturing lot. The system achieves extremely clean trims in this way (Fig B). To prove its stability, each device must maintain initial accuracy after trim during a 48-hour,  $150^\circ\text{C}$  burn-in operation.



**Fig A**—A staircase test matrix helps to optimize focus and power levels in a laser system used for trimming precision thin-film resistors.



**Fig B**—After calibration, a laser-trim system cuts cleanly through a thin-film resistor. The calibration depends on the staircase setup technique of Fig A.



*You can easily achieve a 1-ppm/°C TC by mounting a zener-reference circuit of reasonably low TC on a heated substrate.*

The AD2700 and MAX670 series of hybrid references, for example, use a 1N827 zener diode—chosen for low noise, low dynamic impedance (10Ω max), and good TC linearity. (Why use a hybrid? Fabrication of these TC zener references involves a specialized process, involving extra steps not always available in a standard bipolar process.) The products' initial 10-ppm/°C TC is that of the zener diode. Active laser trimming then lowers the TC by adjusting the zener-diode current, thereby creating additional 3- and 1-ppm/°C product grades (see **box**, "Precision references need laser trimming").

The manufacturer calculates the required zener current using actual TC values, obtained through oven tests on unsealed devices. Note that the amplifier in **Fig 3** supplies current to the zener, which in turn supplies an input voltage to the amplifier. To ensure circuit startup,  $R_4$  supplies current to the zener and the amplifier uses ground as its negative supply, thereby eliminating  $V_{OUT}=0V$  as an unwanted stable state. Note that the amplifier in a zener reference contributes less output noise than does the amplifier in a bandgap reference, because the zener voltage requires less amplification.

### Heater trades $P_D$ for stability

The third type of reference, based on either a bandgap or zener voltage, uses a local heater to maintain the substrate at a constant temperature, usually 10 or 15 degrees above the upper limit of the operating

range. If the circuit's TC is reasonably low (20 to 30 ppm/°C), such a reference can easily achieve a TC of 1 ppm/°C. The disadvantage is power dissipation—an LM199 at -55°C, for example, requires as much as 28 mA at 15V for the heater alone.

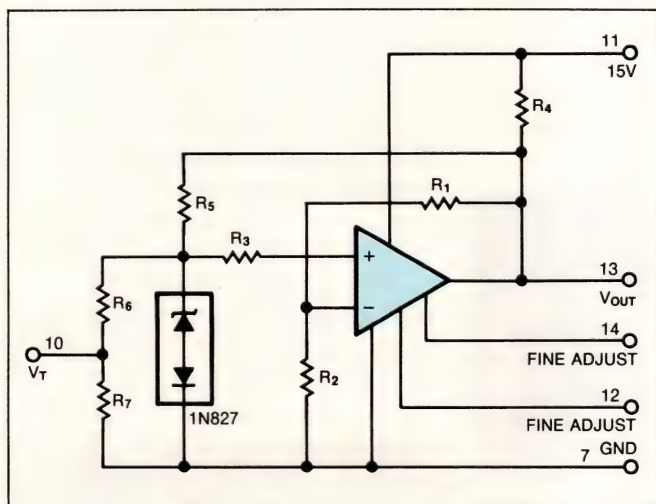
Also, the LM199's output voltage stabilizes at 1 ppm/°C but the initial accuracy is only  $\pm 5\%$ . To meet the  $\pm 0.1\%$  or  $\pm 0.01\%$  tolerances required in data-converter applications, therefore, you must add a precision op amp and scaling resistors and then cope with these components' additional cost and error contributions. The proper evaluation of a reference application involves these issues as well as many of the following ones, which are not always covered explicitly in the data sheet.

Confusion surrounding the specification of temperature coefficient, for instance, is partly a matter of definition. Two definitions are popular. In the "box" method,  $V_{OUT}$  for an in-spec device must remain within a rectangle formed by  $T_{MIN}$ ,  $T_{MAX}$ , and the maximum specified  $\Delta V_{OUT}$  (**Fig 4**).  $\Delta V_{OUT}$  is the product of the nominal output voltage ( $V_{NOM}$ ), the specified TC, and the operating-temperature range. For the AD2700L,

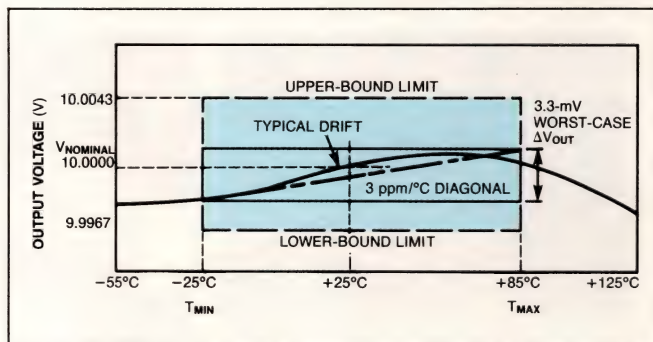
$$\begin{aligned}\Delta V_{OUT} &= V_{NOM} (TC) (T_{MAX} - T_{MIN}) \\ &= 10V(3 \text{ ppm/}^\circ\text{C}) [85 - (-25)^\circ\text{C}] \\ &= 3.3 \text{ mV.}\end{aligned}$$

In other words,  $V_{OUT}$  will change no more than  $\pm 3.3$  mV between any two temperatures in the operating range. This maximum change, added to the  $\pm 2.5$ -mV initial-accuracy spec, produces a total error band of 5.8 mV above and below the nominal  $V_{OUT}$  (10V).

The "butterfly" method, on the other hand, refers everything to 25°C and allows the manufacturer to use



**Fig 3**—The amplifier in this zener-diode reference bootstraps the zener voltage by delivering current to the zener while the zener delivers voltage to the amplifier.  $R_4$  provides start-up current to the zener.



**Fig 4**—In the "box method" of specifying TC, the operating-temperature range and the maximum allowed change in  $V_{OUT}$  form the sides of a rectangle, and the slope of the rectangle's diagonal becomes the TC.



different TCs in determining the error bands at temperatures above and below 25°C (Fig 5). The AD2710K, for example, specs a change of  $\pm 0.9$  mV over the 25 to 70°C range ( $10V \times 2 \text{ ppm}/^\circ\text{C} \times (70-25)^\circ\text{C}$ ). You must add to this the initial tolerance of  $\pm 1$  mV at 25°C, resulting in a maximum possible error of  $\pm 1.9$  mV at  $T_{\text{MAX}}$  (70°C).

Such systems as DVMs and data-acquisition instrumentation often use the box method for specifying total error, because users aren't likely to calculate accuracy using the TC specs. This approach has a disadvantage—the whole 3.3-mV error change in the example of Fig 4 could occur between, say, 25 and 70°C, yielding an effective TC of 7.33 ppm/°C, which exceeds the maximum specified TC (3 ppm/°C). A worst-case analysis over temperature, however, must allow for this much change anyway, regardless of where it occurs in the operating-temperature range.

Because temperature testing plus the reading and recording of data are costly, manufacturers usually base TC specs on only a few data points. These should include at least 25°C and the endpoints ( $T_{\text{MIN}}$  and  $T_{\text{MAX}}$ ). Using the endpoints alone, for example, can make the reference appear better than it actually is if the TC curve is symmetrical and parabolic.

You should avoid using "typical" specs for TC and absolute accuracy; only tested and guaranteed limits for minimum and maximum have meaning. A data sheet should also identify the temperatures used in the calculation of the device's TC. The AD2700L data sheet, for instance, lists 25°C plus the endpoints (–25 and 85°C). The AD2700U data sheet lists these three as well as the extended endpoints of –55 and 125°C.

### Correction yields S curve

Although voltage-reference data sheets seldom specify TC linearity, the characteristic curves for  $V_{\text{OUT}}$  over temperature contain the most useful TC-linearity information that a manufacturer can provide. For bandgap references these curves are parabolic or S-shaped (Fig 6), depending, among other factors, on whether the device includes a linearity-correction circuit. The TC linearity of zener-based references depends mainly on the zener diode, and the reference will include one of two diode types, depending on the intended temperature range and the desired linearity (see box, "Zener diodes determine TC linearity").

Another important specification is noise, which appears on most data sheets as a typical value but seldom has a guaranteed limit. Because noise testing is diffi-

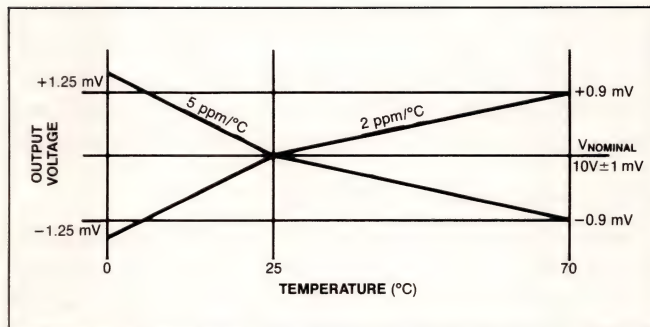


Fig 5—The "butterfly" method of TC specification normalizes the variation of  $V_{\text{OUT}}$  with respect to 25°C. You then extend wing-shaped error bands to the operating-temperature extremes.

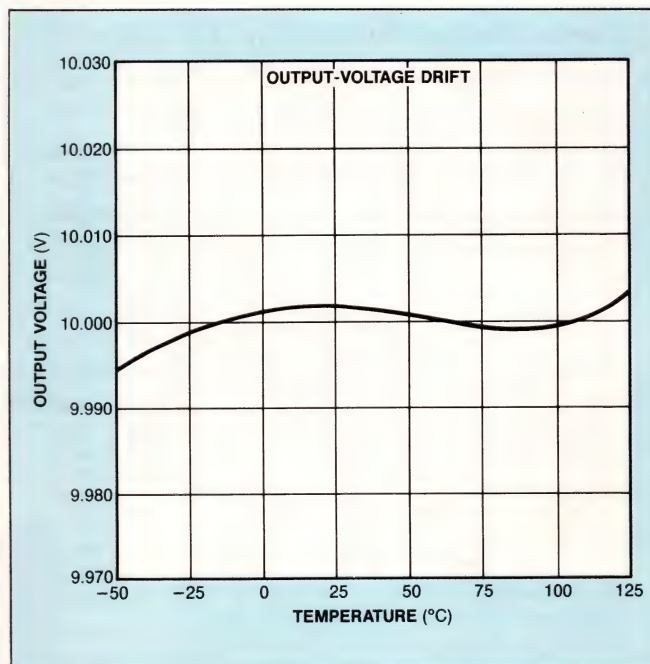


Fig 6—The AD581's  $V_{\text{OUT}}$ -vs-temperature characteristic has an S-shaped curve. This characteristic is typical for bandgap references that include correction circuits for TC linearity.

cult, manufacturers usually guarantee maximum values by performing sample testing only, if that. What's more, because a designer can easily filter or band-limit the higher frequencies by adding capacitors, noise specs cover the 0.1- to 10-Hz range in nearly all cases. (The suppression of low-frequency 1/f noise, however, requires impractically large capacitor values.)

Data sheets usually specify noise in terms of  $\text{nV}/\sqrt{\text{Hz}}$ , an expression that allows you to calculate output noise for the bandwidth of interest. At the same time, you usually convert this quantity to the more useful  $\mu\text{V}$  p-p, especially for converter applications:



*Bandgap references usually have a parabolic TC characteristic that assumes an S shape if the device includes circuitry to effect linearity correction.*

First, multiply  $nV/\sqrt{Hz}$  by the square root of the system bandwidth to obtain the noise magnitude in  $nV$  rms. Then (assuming the noise has a Gaussian distribution), multiplication by 6 will give you the approximate peak-to-peak noise you can expect for that bandwidth.

### Noise measurement is difficult

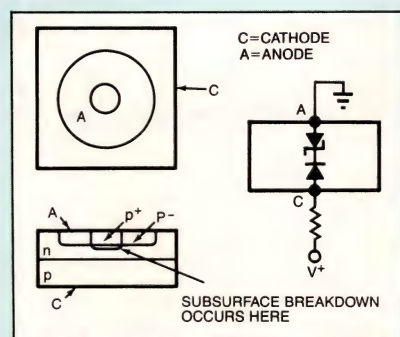
Lack of equipment is part of the difficulty manufacturers face in measuring noise. For example, Quantec makes a noise tester commonly used for testing op amps and transistors, but that instrument requires a nominal 0V bias for the circuit node under test. Spectrum

analyzers make good noise testers, but not many have the dynamic range and the low noise floor necessary to measure, say,  $10\text{-}\mu V$  signals riding on 10V dc. Frequency range is another complication. Spectrum analyzers come in high- or low-frequency models (above or below 100 kHz), so one model doesn't cover the measurement range needed for many applications—0.1 Hz to several megahertz.

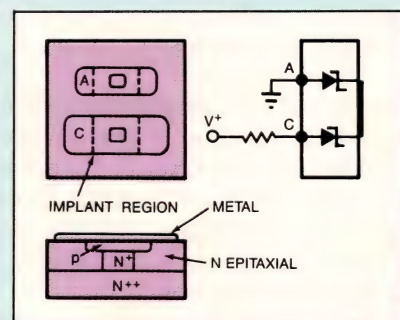
You can measure noise directly using a Tektronix storage oscilloscope with a 7A22 plug-in amplifier, which has  $10\text{-}\mu V/\text{div}$  sensitivity and selectable lowpass and highpass filters that cover 0.1 Hz to 1 MHz. The

## Zener diodes determine TC linearity

The TC linearity for a zener-based voltage reference depends on the type of zener diode in the device. Most hybrid references



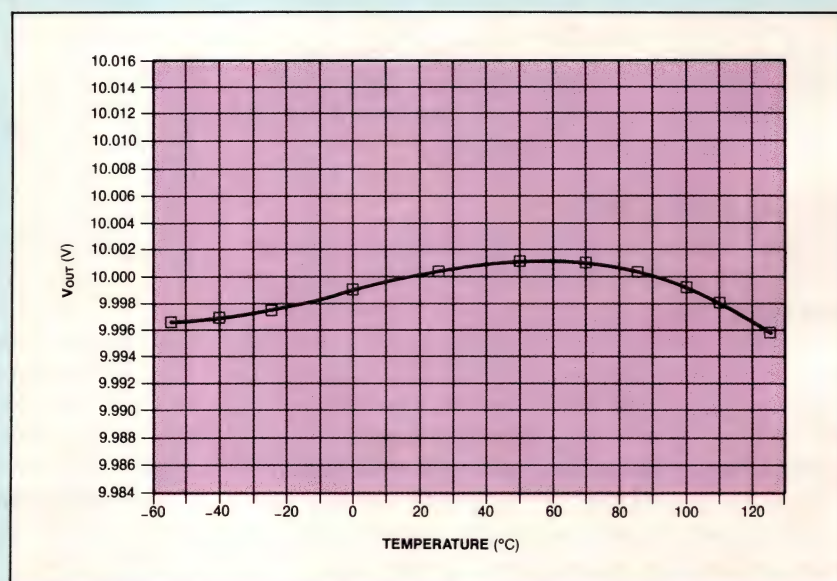
**Fig A—Alloy-diffused zener diodes** feature a vertical configuration in which a top-surface bond pad forms the anode connection and the die substrate forms the cathode connection.



**Fig B—The lateral geometry of ion-implanted zener diodes** places both diode connections on the top surface of the chip.

include one of two types of TC zener (in die form), and only a few zener manufacturers can guarantee 5- to 10-ppm/ $^{\circ}C$  performance for these products. One zener type has an alloy-diffused junction in a vertical configuration (**Fig A**), wherein the anode serves as a bond pad on top of the die and the cathode as the substrate (backside) of the chip.

The other type of zener features an ion implant and lateral geometry (**Fig B**), and has both connections on top of the chip. For this type, the substrate must float unconnected, because the substrate is the junction of two zener diodes—one operating as a zener in the breakdown mode, and the other operating as an ordinary forward-biased diode. The zener voltage is 5.6V,



**Fig C—An ion-implanted-zener reference** such as the AD2700 exhibits a concave-down TC characteristic and better overall linearity than does a diffused-zener type for the range  $-55$  to  $+125^{\circ}C$ .



lowpass settings don't include 10 Hz, however, and the amplifier's input-voltage limitation may require that you ac-couple the signal. The coupling capacitor then forms a highpass filter of a few hertz that precludes the use of the 0.1-Hz highpass setting.

For a more convenient method of noise testing with a storage oscilloscope, you use a low-noise op amp configured for a gain of 100, a 0.1-Hz highpass input filter, and a 10-Hz lowpass output filter (Fig 7). The gain boosts 10- $\mu$ V signals to 1 mV—within the range of most oscilloscopes—and allows use of an OP07A (whose 0.6- $\mu$ V p-p max noise contributes less than 60  $\mu$ V p-p

noise at the output).

To measure noise, set the scope amplifier's vertical-input coupling to dc. Allow the filter to settle and the reference to warm up (about 30 sec in most cases). Clear the screen in storage mode and set the time base for single-trigger mode at 1 sec/div. Set the scope to save mode or maximum screen persistence and measure the peak-to-peak noise for 10 sec. (Observation for 10 seconds is the accepted method, even though the time constant for 0.1 Hz is only 1.6 sec.) A scope photo based on this technique (Fig 8) shows about 20- $\mu$ V p-p noise for the AD581—typical for most bandgap references—

and when operated at the proper current, it produces a TC of 2 mV/ $^{\circ}$ C—a TC equal to and opposite that of the forward-biased diode. For this reason, nearly all temperature-compensated zener diodes have a total voltage of 6.3V (5.6+0.7V). You can create a higher output voltage by connecting multiple forward-biased diodes in series with a higher-voltage zener diode.

Both TC-zener types specify

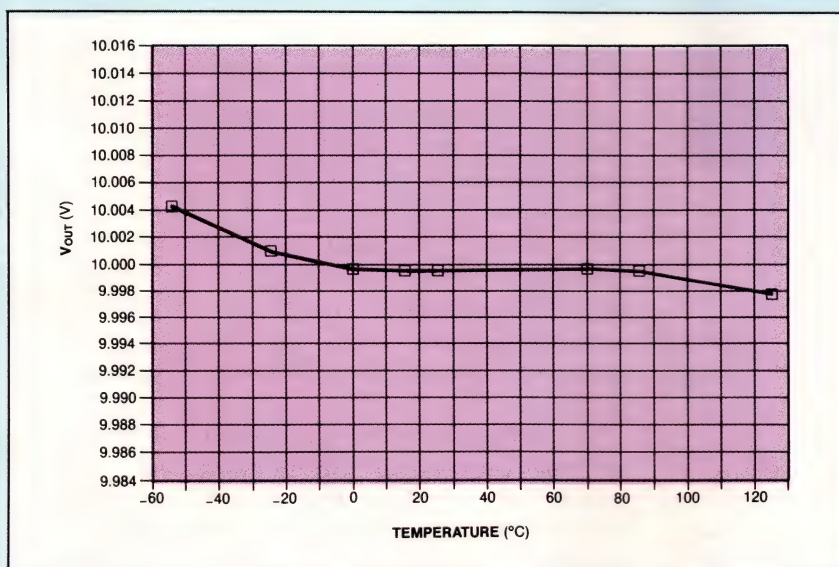
$V_{OUT}$  as 6.3V $\pm$ 5%, but the actual tolerance for ion-implanted types is tighter (typically  $\pm$ 40 mV, or  $\pm$ 0.6%), vs  $\pm$ 300 mV ( $\pm$ 4.7%) for alloy-diffused types. The tighter tolerance of ion-implanted zener diodes allows the reference manufacturer to target gain-resistor values more closely, do less laser trimming, and thereby provide better  $V_{OUT}$  stability.

TC linearity is the most no-

ticeable difference between the two zener types. The implanted zener's concave-down curve exhibits better overall linearity from -55 to 125 $^{\circ}$ C (Fig C), but the diffused zener has better TC linearity from 0 to 70 $^{\circ}$ C (Fig D). Both the forward-biased diode and the zener diode contribute to the nonlinearity, and these effects increase at low current.

Accordingly, most TC zeners have operating currents in the 0.5- to 7.5-mA range, which is an order of magnitude higher than that of zeners normally found in an IC. High current (sufficiently beyond the value at the zener's breakdown voltage) also ensures low noise.

Though it's a tedious procedure, you can always characterize the reference over temperature and then compensate for the TC nonlinearity by using a temperature sensor, A/D converter, and software lookup table. The well-controlled ion-implant process offers a compromise solution, however—the use of zener diodes in which the TC curves and 25 $^{\circ}$ C voltages are repeatable from lot to lot.



**Fig D—**The output of a diffused-zener reference such as the AD2710 provides excellent TC linearity from 0 to 70 $^{\circ}$ C, but suffers in linearity outside that range.



Often, the statistical data taken by the manufacturer on life-test samples is the best stability information you can obtain about a reference.

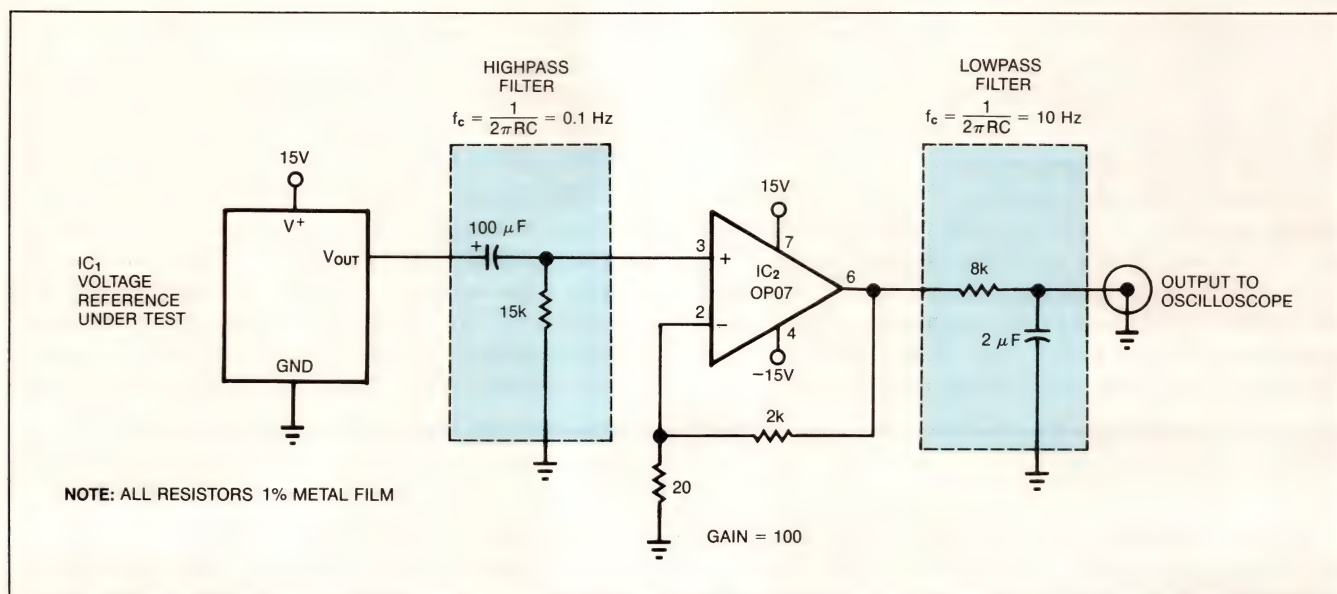


Fig 7—Introducing highpass and lowpass filters and a low-noise op amp lets you measure voltage-reference noise using a storage oscilloscope.

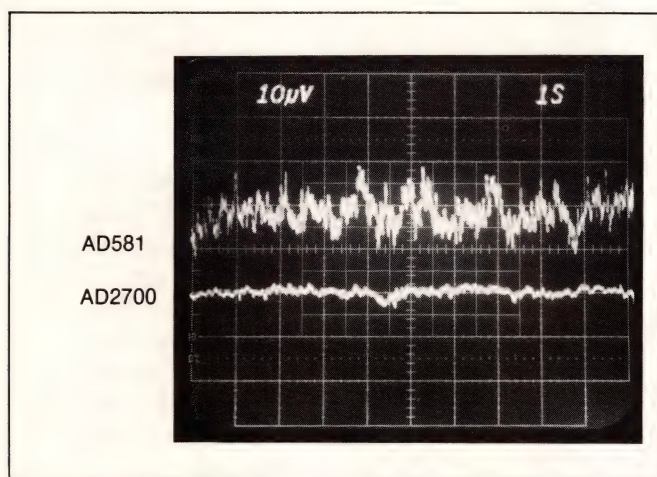


Fig 8—This scope photo shows the noise levels typical for a bandgap reference (upper trace) and a zener-based reference (lower trace). The scale is 10  $\mu$ V/vertical div; 1 sec/horizontal div.

and about 5  $\mu$ V p-p for the AD2700 zener reference. Table 1 compares noise for these devices over different bandwidths.

### Long-term stability

Long-term stability can be the most important spec in a reference application, but—as in the case of noise—this parameter seldom receives a thorough characterization in the data sheet. Most manufacturers specify stability as 25 to 100 ppm (typ) per thousand hours at 125°C. They cannot accurately extrapolate this stability

TABLE 1—REFERENCE-NOISE COMPARISON

BANDWIDTH	NOISE ( $\mu$ V p-p)	
	AD581 (BANDGAP)	AD2700 (ZENER)
0.1 TO 10 Hz	20	5
1 TO 100 Hz	50	8
1 Hz TO 3 kHz	220	30
1 Hz TO 300 kHz	600	200

data to other temperatures because those temperatures may activate other mechanisms of instability. Nor can they guarantee a maximum limit by testing all parts for 1000 hours, because 100% burn-in testing costs too much. (And in any case, the manufacturer cannot guarantee a reference's stability for the second 1000 hours.) The solution, therefore, is to either test samples only or to guarantee this spec "by design" (in other words, the manufacturer will replace customer parts that fail).

Often, the best reference-stability information that a customer can obtain is the statistical data taken by the manufacturer on life-test samples. Maxim, for example, records long-term stability for a set of sample devices operating continuously for several thousand hours at 55°C (a realistic operating temperature that is higher than the room ambient temperature but lower than  $T_{MAX}$ ). Such data (Fig 9) for the AD2700, for instance,





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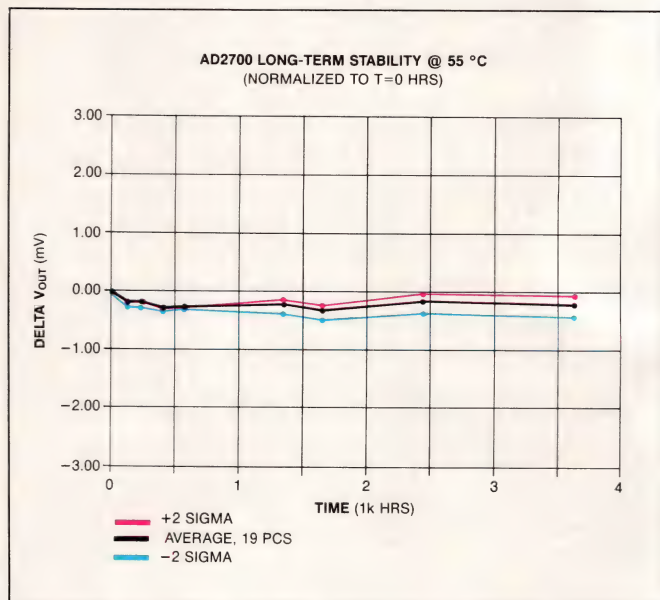
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*Output-current specs are misleading unless they specify  $V_{OUT}$  limits such as those in the spec for load regulation.*



**Fig 9—The average stability of AD2700 voltage references over 3600 hours at 55°C appears in the center curve. The upper and lower curves denote 2-sigma boundaries that encompass 90% of the 19 units tested.**

shows that  $V_{OUT}$  drifts about 250  $\mu V$  negative and then remains within  $\pm 50 \mu V$  of that level. The center curve represents typical performance; the upper and lower "2-sigma" curves encompass 90% of the devices, based on the standard deviation of measured values.

#### **$I_{OUT}$ specs can be misleading**

Output-current specs are misleading unless they specify  $V_{OUT}$  limits such as those included in the spec for load regulation. Note how this parameter reveals important differences in several reference devices. The AD2700, for example, has a 741-type output circuit that can sink and source current equally well within a range of  $\pm 10$  mA.  $V_{OUT}$  changes 0.5 mV max for a 0- to 10-mA change in output current, resulting in a load regulation of 50  $\mu V$ /mA max.

The MAX671 has Kelvin outputs that provide load regulation of 10  $\mu V$ /mA max. The 10V REF01 monolithic reference, on the other hand, has a simple emitter-follower output that can only source current (to ground); its load regulation is 1 mV/mA max over 0 to 10 mA. For the AD580, this same 1-mV/mA limit represents lower performance because  $V_{OUT}$  is only 2.5V. The 10V references AD581 and AD584 can source as much as 10 mA at 25°C but specify the load regulation (500  $\mu V$ /mA max) to only 5 mA. These two devices have limited current-sinking capability over the MIL

temperature range. They guarantee 5-mA source current over the full operating-temperature range.

#### **Measure $V_{OUT}$ vs $V_{SUPPLY}$**

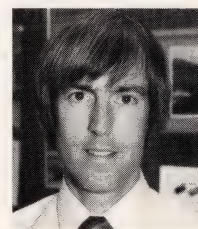
Line regulation and power-supply rejection ratio (PSRR) are two other important parameters for voltage references. They represent the change in  $V_{OUT}$  that results from fluctuations in supply voltage. Line regulation is a dc test whose results are usually expressed in  $\mu V/V$  or mV/V. PSRR can be a dc test, but usually the test conditions for this parameter include a range of frequencies or a specific frequency. The line-regulation spec has the advantage that self-heating effects are included in the output-voltage change. PSRR, on the other hand, has more realistic test conditions. At 60 Hz in particular, self-heating effects average out but the power supply may offer poor regulation, degrading the stability of  $V_{OUT}$ .

Finally, consider the implications of temperature hysteresis in your application. A reference output  $V_{OUT1}$  at temperature  $T_1$  should return to  $V_{OUT1}$  after you cycle the device to  $T_2$  and back to  $T_1$ . If not, the output exhibits hysteresis. The cause is thermal stress within the IC, which in turn causes expansion of the silicon with temperature—and this effect is aggravated by the contact of dissimilar packaging materials that have different coefficients of expansion. With the exception of that for the LT1021 (Linear Technology Corp, Milpitas, CA), voltage-reference data sheets rarely mention hysteresis.

**EDN**

#### **Author's biography**

Ron Knapp is a senior member of the technical staff at Maxim Integrated Products (Sunnyvale, CA). He holds a BS in systems engineering from Boston University, an MSEE from Worcester Polytechnic Institute, and is vice president of the Northern California Chapter of The International Society for Hybrid Microelectronics (ISHM). In his spare time, Ron enjoys flying and sailing.



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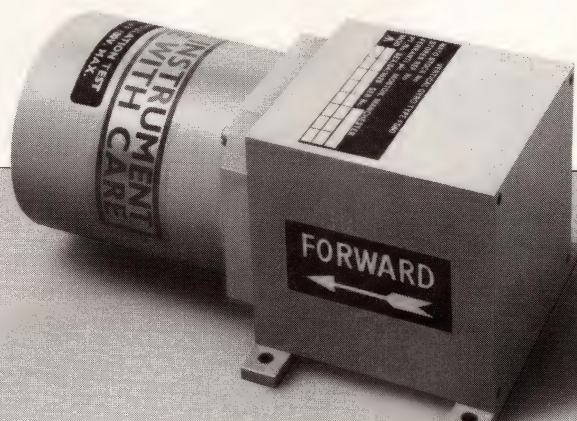
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			○		GLSUR3K	2400	3000	
				○	GLSUR3K1	2400	3000	
			○		GLSUR46	250	400	
				○	GLSUR2K6	1400	2000	
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		○			LT9552L	80	200	
				○	LT9550EL	120	250	
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				○		TBD	60	Red
							40	Yellow-green
	10φ			○	LT9512U	4000	5000	Red
		○			LT9562U	700	1400	

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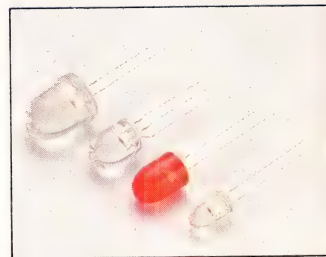
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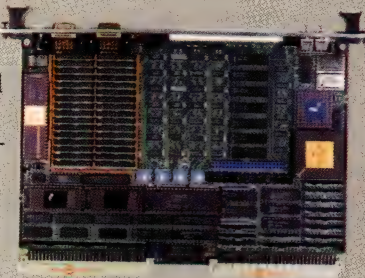
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# Serial techniques expand your options for $\mu$ C peripherals

---

*The Serial Peripheral Interface (SPI) bus of the MC68HC11 microcomputer is flexible enough to let you attach devices designed for other serial buses—Signetics' IIC peripherals, for instance, or ITT's IM family.*

---

Naji Naufel, *Motorola Inc*

Designers usually assume that basing a system upon a particular single-chip microcomputer unit (MCU) will restrict their choice of peripherals to those for which interface functions are available on the MCU or on subsystem chips of the same family. Unfortunately, peripheral family members may not be adequate to meet the needs of your application. For a system based on the Motorola MC68HC11, however, you can expand your options by attaching serial devices to the MC68HC11's SPI bus. This bus is adaptable enough to work with serial devices designed for other buses, such as the Signetics family of Inter-Integrated-Circuit (IIC) peripherals and the ITT family of Intermetall (IM) peripherals.

Although devices in the Signetics and ITT families aren't directly compatible with the MC68HC11 microcomputer, it's not difficult to attach them, as slave

devices, to the Motorola SPI bus. You'll find it fairly straightforward, for instance, to connect two relatively simple devices, a clock/timer from the IIC family and an EEPROM from the IM family, to the MC68HC11's bus. If you want to attach more complex devices from either family, you'll probably need to study the source documentation (Refs 1, 2, and 3), but the schematics and software routines that follow will be adequate as a starting point. For additional information about the registers to which the software routines refer, see **box**, "Three registers control the SPI."

## Interbus connections are simple

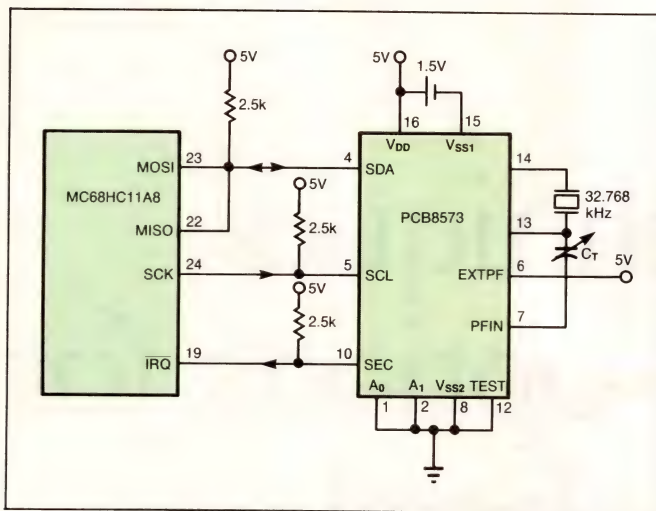
The SPI consists of little more than an 8-bit shift register with separate lines for incoming and outgoing data, and a third line that carries the shift clock. The protocol is simple; you set the interface for a read or a write operation and generate eight clock pulses to shift the data in or out, sending the most significant bit (MSB) first.

The IIC bus has a single, bidirectional data line and a clock line, but the transmission protocol is a little more complex; it requires both a start and a stop condition. In addition, the clock sequence consists of nine pulses; eight of these pulses shift the data bits in or out (MSB first), and the ninth allows a slave device to acknowledge receipt of the data byte.

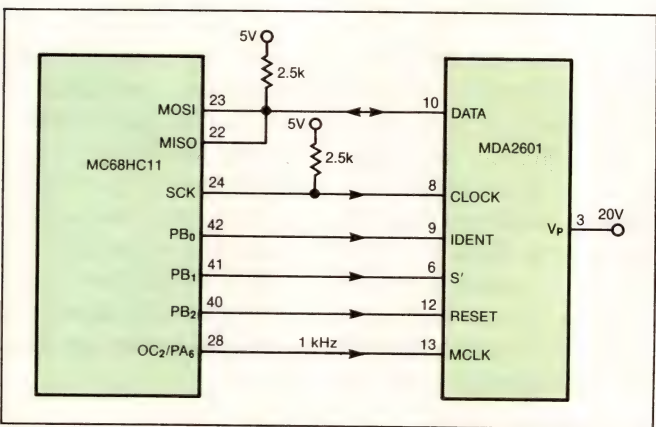
The IM bus also has a bidirectional data line and a clock line, but in addition it requires an IDENT line that distinguishes between an address and a data byte.



Because you can configure the SPI lines as open-drain circuits, you can connect both the serial-input and serial-output lines to the bidirectional data line of a peripheral.



**Fig 1—**You need only three lines to connect the PCB8573 clock/timer from the Signetics IIC family to the SPI bus of an MC68HC11A8 microcontroller.



**Fig 2—**Serial peripherals of the ITT Intermetall family, such as the MDA2601 EEPROM, need part of a parallel port for control purposes, as well as the SPI, for data transmission.

Unlike the other two buses, IM devices send the least significant bit (LSB) first. Therefore, if you're interfacing the SPI to an IM device, you must provide a software routine to reverse the bit order before sending and after receiving a data byte.

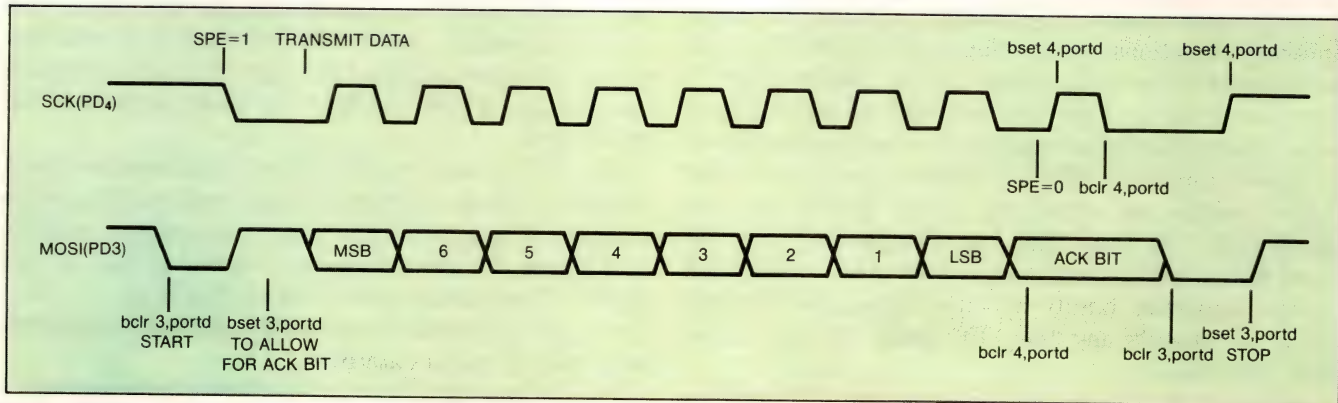
**Fig 1** shows how to connect an IIC clock/timer chip to the SPI bus, and **Fig 2** shows the connections for an IM EEPROM. In both cases, you have to connect the MOSI (master out, slave in) pins of the 68HC11 microcomputer to the MISO (master in, slave out) pins and to the bidirectional data pin of the peripheral device. Because the MOSI pin is part of an internal open-drain circuit, you need a pullup resistor on the line.

For this type of configuration, you send data to the peripheral merely by writing the data byte to the shift register (SPDR). To receive data from the peripheral, you generate receive shift-clock pulses by writing FF<sub>HEX</sub> to the transmit register as if you were sending it. Again, because the MOSI line is part of an open-drain circuit, incoming data bits that are set to 1 don't affect the MOSI/MISO line status (which defaults to high because of the FF<sub>HEX</sub> in the transmit register); incoming bits that are set to 0, however, can pull the line low without difficulty.

### IIC software uses only port D

The software that lets you emulate the IIC protocol takes advantage of the MC68HC11's ability to use its port D pins either as SPI pins (when the SPI is enabled) or as general-purpose, independent I/O pins (when the SPI is disabled). The sample software of **Listing 1** (pg 203) makes use of this feature to generate the timing shown in **Fig 3**.

To initialize the interface, turn off the SPI (SPE=0) and set bits 3 and 4 of port D high to generate the idle



**Fig 3—**By turning off the SPI, you can use its pins as independent I/O lines. Thus, you can interface the MC68HC11 MCU to IIC peripherals without using any other ports, as this timing diagram shows.



condition of the MOSI and SCK lines. To send a byte to the peripheral, you first load the byte into the B accumulator and then generate a start condition by clearing bit 3 of port D while leaving bit 4 high. Next, you turn on the SPI; this action forces the SCK line low and the MOSI line high (CPOL=CPHA=0) and causes the MCU to transmit the eight data bits.

When all the data bits have been shifted out, you

clear bit 4 of port D, then turn off the SPI and generate the acknowledge clock pulse by first setting, then clearing, bit 4 of port D. Finally, after the last byte has been sent, you call the Stop subroutine to generate a stop condition by setting bit 3 of port D high while bit 4 (the clock line) is in the idle (high) state.

Devices that use the IM bus examine the IDENT line; because this line must be held low throughout the

## Three registers control the SPI

The SPI (Serial Peripheral Interface) allows you to use the MC68HC11 microcomputer's I/O port D to communicate with a peripheral device over a simple serial link. The three main registers are the SPI control register (SPCR), the SPI data register (SPDR), and the SPI status register (SPSR) (Fig A).

The SPCR stores control words sent by the processor via the microcomputer's internal data bus. The SPE bit enables or disables the SPI; the CPOL bit determines the polarity (high or low) of the SCK clock line in the idle condition; the CPHA bit determines which edge of the SCK clock latches data into or out of the shift register; the MSTR bit determines whether the SPI will act as a master or as a slave; and the two SPR bits select the shift-clock rate. The DWOM bit, when set to 0, configures the six port D pins as normal CMOS outputs; when set to 1, it configures these pins as open-drain outputs.

The SPDR consists of a read-data buffer and a shift register. To write data to a peripheral, you load the shift register directly; a second write instruction, issued before the current byte has been completely trans-

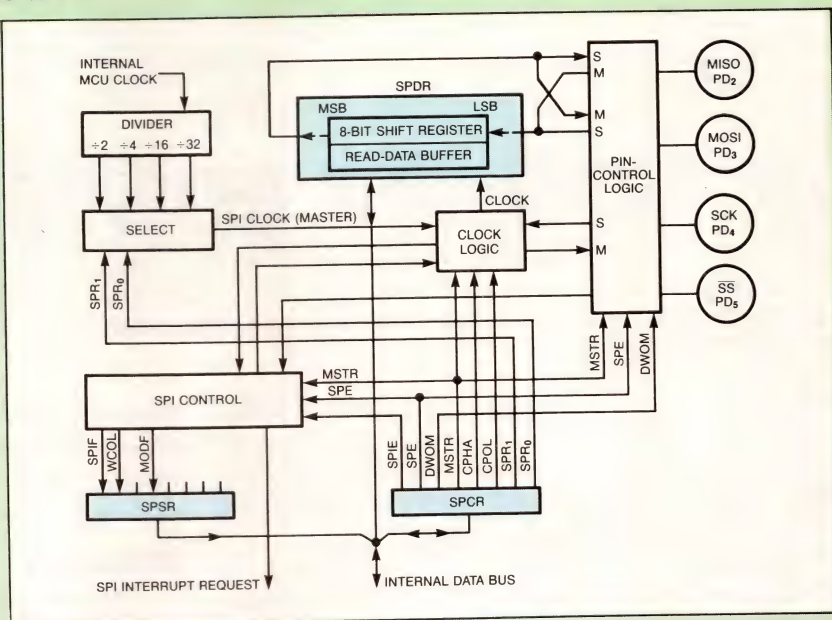


Fig A—The SPCR, SPDR, and SPSR registers provide control of the SPI, transmit/receive facilities, and status information.

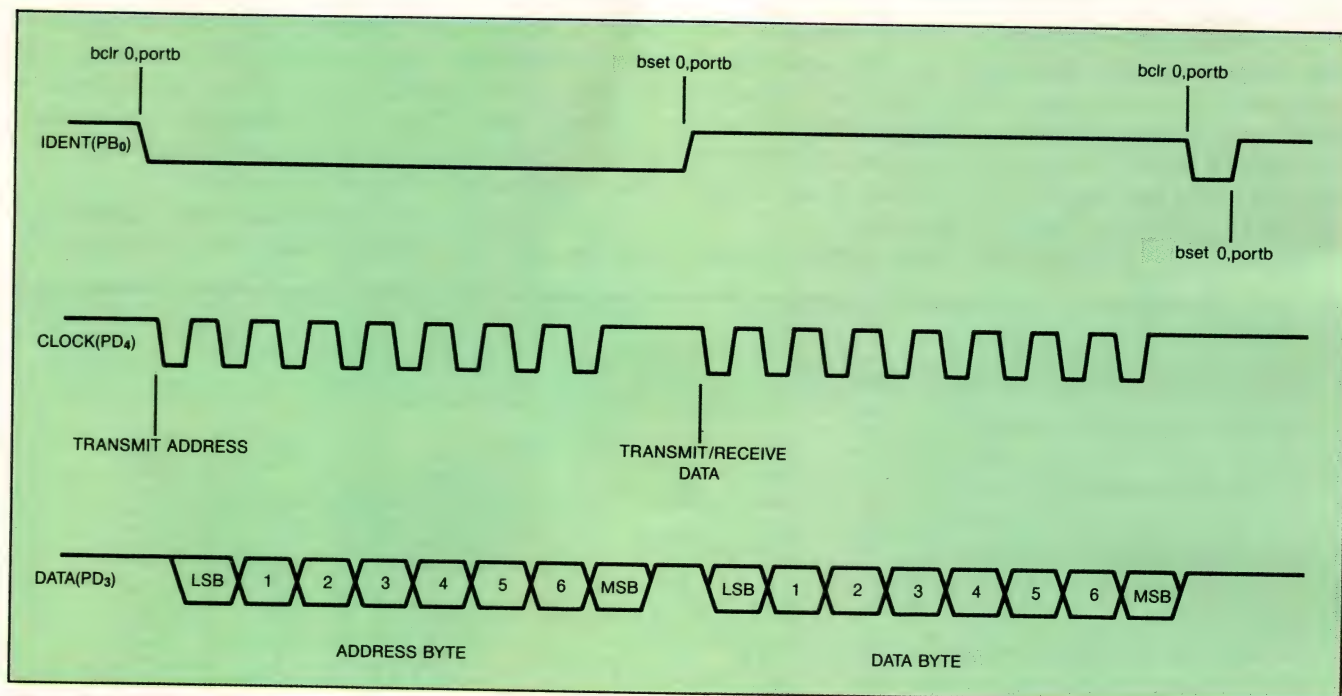
mitted, will be ignored. During a read operation, however, an incoming byte is automatically transferred to the buffer as soon as the last bit has been clocked into the shift register; therefore you have one byte-time in which to fetch the byte, while the next byte is filling the shift register.

In the SPSR, the completion of a data transfer between the MCU (microcomputer unit) and the peripheral device, in either direction, sets the SPIF bit (transfer-complete flag). To clear

the SPIF, you must first read the SPSR and then read or write the SPDR. When the SPIF is set, failure to read the SPSR will inhibit any attempt to write to the SPDR. Attempting to write to the SPDR while a data transfer is in progress will set the WCOL bit (write-collision flag) and inhibit the write operation. To clear the WCOL bit, you must first read the SPSR and then write the data byte to the SPDR.



*To communicate with the IM bus, you must reverse the bit order of each byte before sending it or after receiving it.*



**Fig 4—The IDENT line of ITT's line of Intermetall peripherals distinguishes between addresses and data. As you can see from this timing diagram, you need a separate port to control the IDENT line.**

transmission of eight address bits and high while data is being read or written, you can't drive it from port D, which the SPI needs for serial data and shift clock pulses. Instead, drive the IDENT and other IM control lines from port B (Listing 2 (pg 204), Fig 4).

You initialize the SPI with CPOL=CPHA=1. To send data to a peripheral, you force the IDENT line low and transmit the 8-bit peripheral address. Then, while holding IDENT high, you send (or read) the eight data bits. When all the address and data pairs have been sent, you drive IDENT low and then high again to create a short pulse, which generates a stop condition.

As with the IIC bus, you transmit FF<sub>HEX</sub> to generate shift-clock pulses for a read operation; the resultant high on the MOSI line doesn't interfere with incoming data bits. Remember, too, that the IM bus requires that you transmit the LSB first, whereas the SPI requires the transmittal of the MSB first; to meet this condition, the "flip" subroutine of Listing 2 reverses the bit order before you load a byte into the transmit shift register and after a complete byte has been assembled in the receive shift register.

Although the preceding diagrams and subroutine listings relate to specific peripherals, you can easily adapt the basic techniques to connect any peripheral of the IIC or IM families to the SPI bus of a 68HC11-based

system. Conceivably, you can even apply the same principles to other families of serial peripherals to extend your options still further.

**EDN**

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1. MC68HC11A8 HCMOS Single-Chip Microcomputer, Technical Data Sheet MC68HC11A8/D, Motorola Literature Distribution Ctr, Box 20912, Phoenix, AZ 85036.
2. Fenger, Carl K, "Bus links peripherals, multiple masters in low-speed network," *EDN*, April 3, 1986, pg 153.
3. CCU 2000/2030 microcontroller data sheet, ITT Corp.

## Author's biography

At the time he wrote this article, Naji Naufel was an MCU applications engineer with Motorola (Austin, TX); since then he has become a product engineer responsible for testing 8-bit MCUs and improving yields. Naji holds a BSEE from the University of Texas. In his spare time, he enjoys tennis, photography, and flying radio-controlled model aircraft.



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## LISTING 1—ICC BUS SUBROUTINE

```

*****
* This subroutine transfers a byte from the HCL1's SPI to the IIC
* peripheral. Upon entry, data is in Acc B.
* w_start is the entry point for sending a start bit.
* nostart is the entry point for transferring data without a
* start condition.
*****
*
w_start      equ      *
              bclr     portd,x $08      start condition (bclr 3, portd)
nostart      equ      *
              ldaa     spcr,x
              oraa     #$40             enable SPI (SPE=1)
              staa     spcr,x
              bset     portd,x $08      return PD3 to idle state (bset 3,portd)
              stab     spdr,x          write data
wait         ldaa     spsr,x          wait for ewnd of transmission
              bpl      wait           SPIF not set, wait.
*
              bclr     portd,x $10      bclr 4,portd to leave SCLK (PD4) low
              ldaa     spcr,x          create ACK clock pulse
              anda     #$bf            clear SPE, disable SPI
              staa     spcr,x          causes PD4 to go high
*
              tst      ack             test acknowledge flag
              bne      hi_ack          keep ACK high
lo_ack       bclr     portd,x $08      else, clear ACK bit (bclr 3,portd)
              bsr      hi_ack          generate ACK clock
              bset     portd,x $08      bring ACK bit high (bset 3,portd)
              rts                    return to caller
*
hi_ack       bset     portd,x $10      generate ACK clock (bset 4,portd)
              brn      hi_ack          ensure clock-pulse width
              bclr     portd,x $10      bclr 4,portd
              rts                    return to caller

*****
* This subroutine creates a stop condition
*****
*
stop         equ      *
              bclr     portd,x $08      bring SDA low (bclr 3,portd)
              bset     portd,x $10      bring SCL high (bset 4,portd)
              bset     portd,x $08      bring SDA high (bset 3,portd)
              rts                    return to caller

*****
* This subroutine sends an address byte, followed by a control
* byte in CONTROL
*****
*
addrcntl     equ      *
              ldab     #waddr          r/w=0
              bsr      w_start         send address with start condition
              ldab     control
              bsr      nostart          send control byte without start
              rts                    return to caller

*****
* This subroutine reads a data byte
*****
*
read         equ      *
              ldaa     #$00
              staa     control
              inca
              staa     ack             high ack bit (ack nonzero)

```

*Listings continued on pg 204*



## LISTING 1—ICC BUS SUBROUTINE (Continued)

```

jsr    addrcntl    send address/control bytes
jsr    stop
ldab   #raddr      r/w=1
bsr    w_start     send address with start condition
clr    ack         low ACK bit
ldab   #$ff        and read 4 data bytes
bsr    nostart     keep MOSI open-drain high
ldaa   spdr,x      get received data
staa   ram+2       HOURS
ldab   #$ff
bsr    nostart
ldaa   spdr,x
staa   ram+3       MINUTES
ldab   #$ff
bsr    nostart
ldaa   spdr,x
staa   ram+1       DAYS
inc    ack         high ACK bit for last byte received
ldab   #$ff
jsr    nostart
jsr    stop        end session
lda    spdr,x
staa   ram         MONTHS
rts                     return to caller

```

\*  
 END OF LISTING 1  
 \*\*\*\*\*

## LISTING 2—IM BUS SUBROUTINE

\*\*\*\*\*  
 \* This subroutine reverses the order of the bits in a byte. The input  
 \* data is in Acc A, and the output is returned in Acc B. The action  
 \* shifts the data out of the MSB side of Acc A into the MSB side of Acc B.  
 \*\*\*\*\*

```

*
flip    equ    *
ldab   #$08    do it 8 times
stab   temp
again   asla
        rorb
        dec    temp
        bne    again
rts

```

\*\*\*\*\*  
 \* This subroutine sends two bytes to the IM peripheral; the first byte  
 \* is in ADDR, the second byte is in DATA.  
 \*\*\*\*\*

```

*
im_send equ    *
ldx     #$1000    point X to register base address
lda     ADDR      address register
bsr     flip      reverse the bit order
bclr    portb,x %00000001 clear IDENT (PB0)
stb     spdr,x    send byte (address register)
ldaa    DATA     get address
bsr     flip
brclr   spsr,x %10000000 wait for SP]I flag
bset    portb,x %00000001 set IDENT (PB0)
stb     spdr,x    send word
brclr   spsr,x %10000000 wait for SPI flag
bclr    portb,x %00000001
bset    portb,x %00000001 toggle IDENT (PB0)
rts                     return to caller

```

\*  
 END OF LISTING 2  
 \*\*\*\*\*



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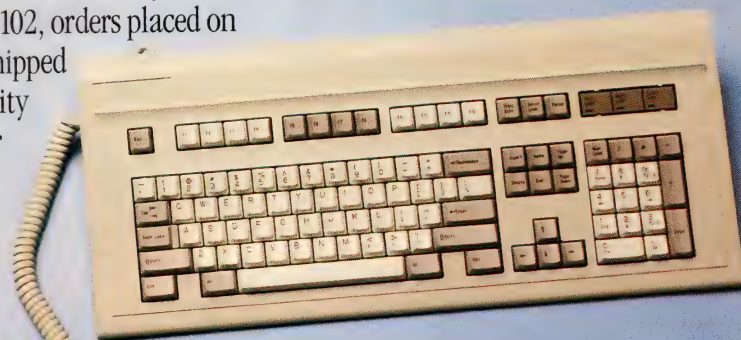
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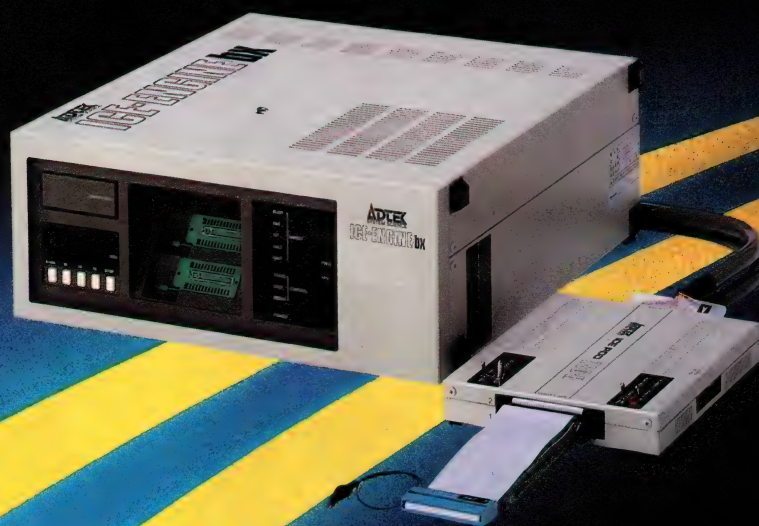
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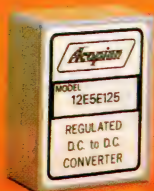




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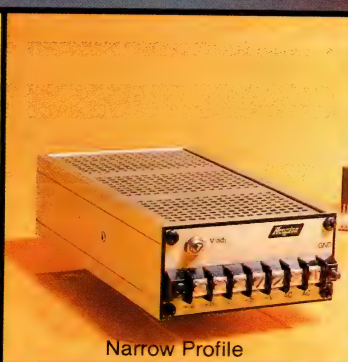
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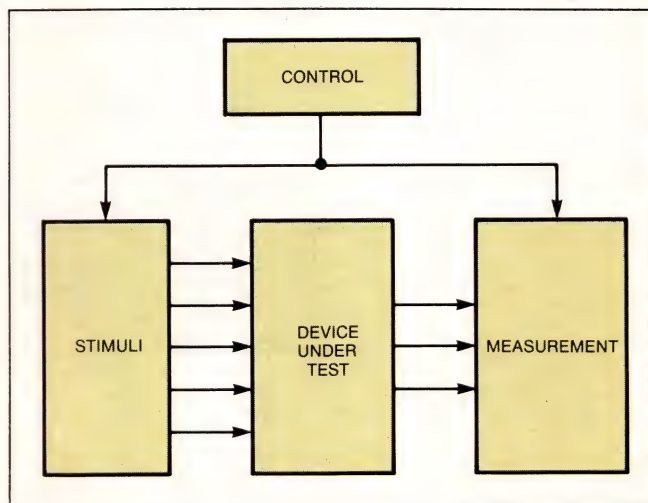


# Programmable-delay ICs control system timing

*Low cost, low power, and small package size extend the application of digital-to-time converters in system timing applications. By exploiting the programmability features of these devices, you can both simplify timing-system design and gain greater control of timing parameters than you can by using analog time-delaying methods.*

Craven Hilton and Jeff Barrow,  
*Analog Devices Inc*

Accurate control of pulse timing is extremely important in digital electronic systems in those applications where system requirements dictate digital control of delays. Until now, you've had to use an analog method, employing a high-speed comparator to detect the incremental delays on a linear ramp, and a D/A converter to set the threshold level of the comparator. This design uses as much as one watt of power; now, however, monolithic digital-to-time converters (DTCs), such as the AD9500, accomplish the same function while only dissipating 300 mW. You can use the AD9500 to control time delays having intervals as small as 10 psec in a full-scale span of 2.5 nsec min.



**Fig 1—This test configuration, typical of virtually all electronic measurement systems, comprises four blocks: stimuli, control, measurement, and the device under test.**

Some circuit examples illustrate the benefits of using a monolithic DTC in such applications as LSI and VLSI automatic test systems, which present significant challenges in pulse generation and distribution. For instance, although you can achieve repeatable delays of less than 100 psec by using an analog technique with an RC time reference, this method will not provide you with *variable* delays having such short intervals. The key to the flexibility of the monolithic DTC is the device's programmability.

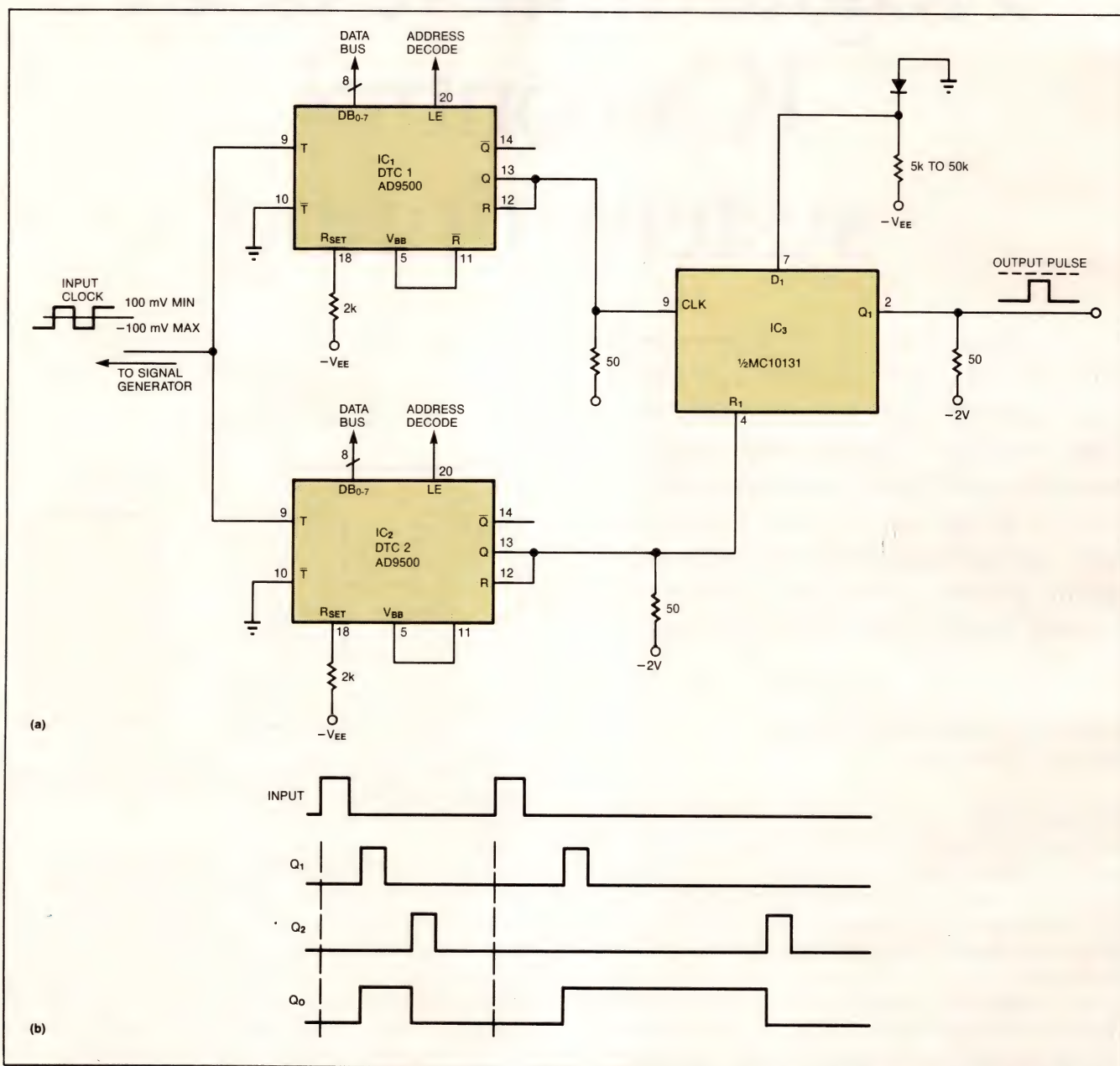
Fig 1 is a generic block diagram of virtually all



*By exploiting a DTC's programmability, you can simplify timing-system design and gain more precise control of timing parameters.*

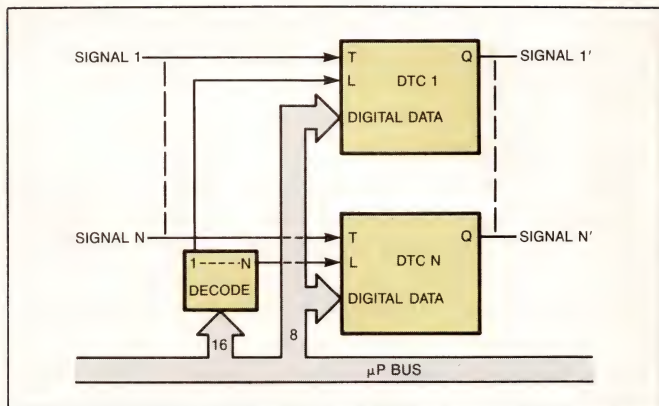
electronic measuring systems. Such a system can evaluate any device (the device under test, or DUT) for virtually any performance criteria if you apply the proper stimuli and use the appropriate measurement circuits. This electronic measuring system will serve as a model for the timing circuits throughout the remainder of the text.

One way to exploit the programmability of the DTC is to use two DTCs triggered from the same clock to program both the leading and trailing edges of an output pulse. This application is illustrated in Fig 2a. The first DTC (IC<sub>1</sub>), which produces the leading edge of the output pulse, drives the clock input of IC<sub>3</sub>, a D-type flip-flop whose D input is tied to a logic one. After IC<sub>1</sub>



**Fig 2—Two DTCs control the output's leading and trailing edges in this digitally controlled pulse generator. The timing diagram in **b** brings out the fact that the leading edge of the output pulse, Q<sub>0</sub>, occurs after an interval equal to the propagation delay plus the programmed delay.**





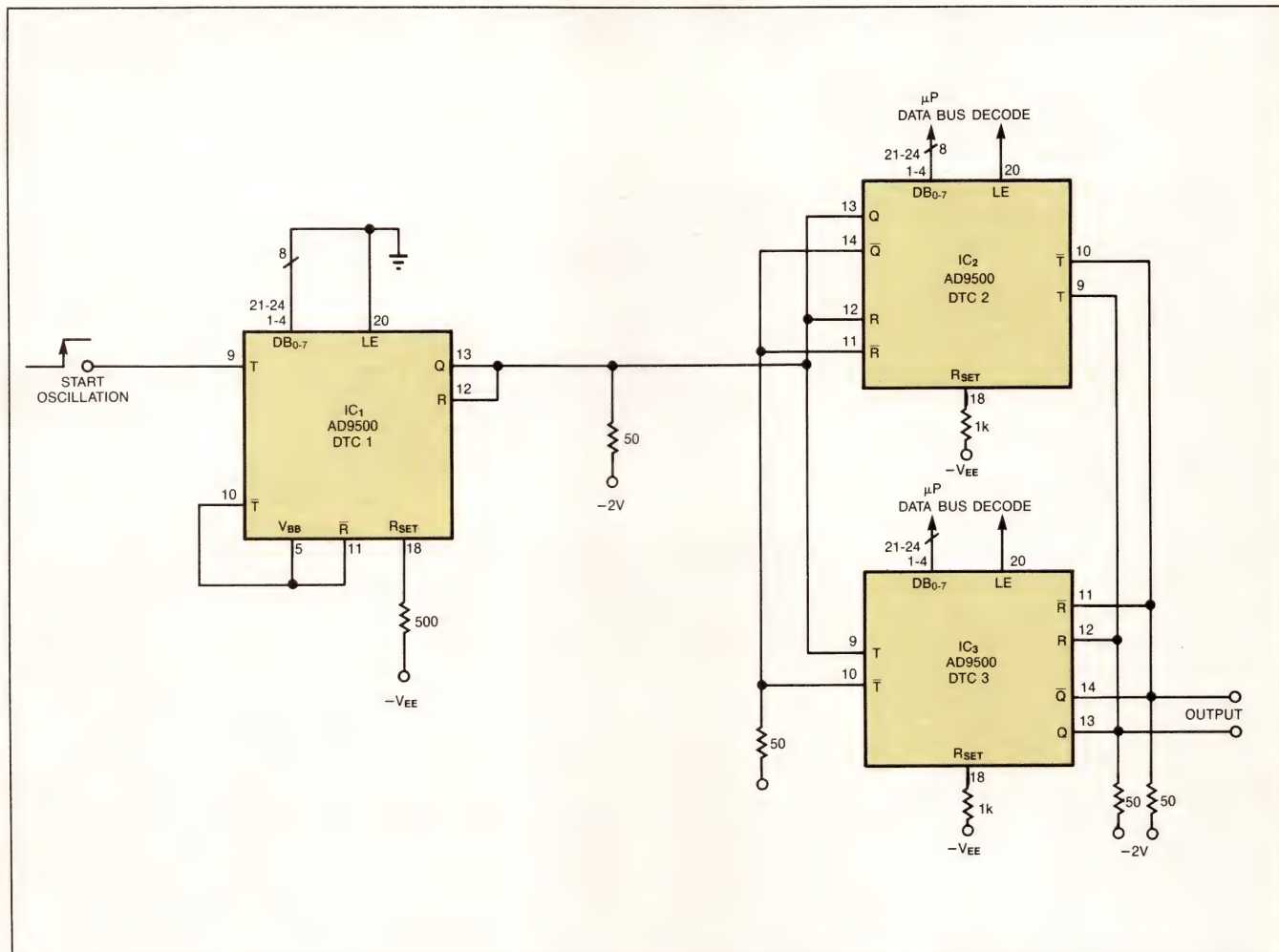
**Fig 3—Providing precise delay matching in critical applications,** this circuit uses multiple DTCs to compensate for differences in the delays inherent in different signal paths. The closed-loop circuit provides a deskewing function.

clocks the one through the flip-flop, the second DTC (IC<sub>2</sub>) resets the flip-flop, thereby producing the falling edge.

At a time equal to the propagation delay plus the programmed delay of the first DTC (**Fig 2b**), the flip-flop produces the leading edge of the output pulse. Because the propagation delays of the two DTCs cancel each other, the width of the output pulse is exactly the difference between the programmed delays of the two DTCs. You can determine the programmed delay of each DTC from

$$t_D = t_{PD} + \frac{XX_{16}}{FF_{16}} (R_{SET} C_{SET}).$$

The circuit of **Fig 3** provides precise delay matching for those applications in which you need to distribute a



**Fig 4—Using DTCs configured to start and stop the oscillation,** this digitally programmable oscillator gives you complete control over the start-up, shutdown, and frequency of oscillation.



*You can use multiple digital-to-time converters to construct oscillators, deskewing circuits, and accurate delay-measurement systems.*

number of pulses and maintain good coherence between those pulses. Because individual test circuits may have extraneous delays in the signal paths to the DUTs, close matching in the initial tester delays will not be sufficient to guarantee close matching between the delivered pulses. The combination of programmable deskewing circuitry and the closed-loop calibration scheme of Fig 3 allows you to compensate for the timing variations in the circuit paths during your test-system setup cycle.

During the setup cycle, the closed-loop system measures the delay to each input pin of the DUT. It then modifies the delay values stored in each of the DTCs until the input pulses arrive at the DUT's pins simulta-

neously. This method allows you to match the delays to the DUT to a resolution of 20 psec for a full-scale delay period of 5 nsec.

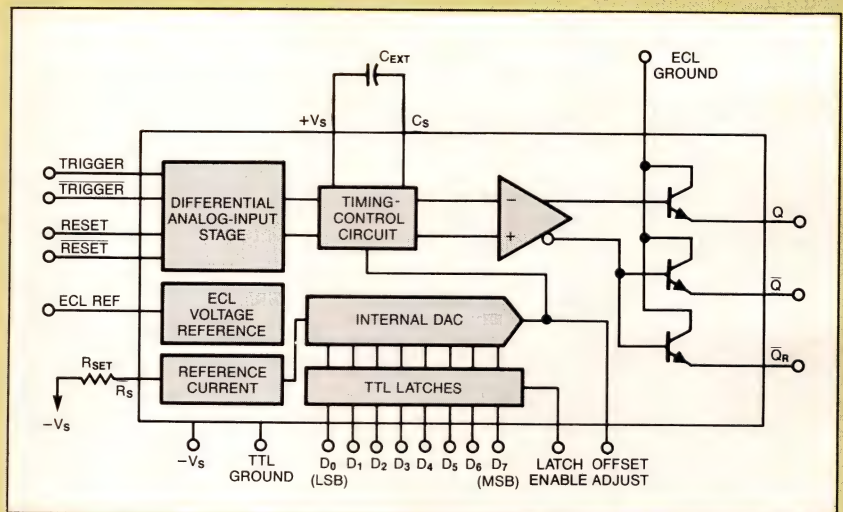
### Programmable oscillator

Fig 4 shows that you can also create a digitally programmable oscillator by using three DTCs. IC<sub>1</sub> acts as a start-up pulser to trigger the other two DTCs, which are configured as astable oscillators interconnected in a wired-OR configuration. You can generate the start-oscillation pulse locally, or you can use the system power-up-reset signal to generate the start-oscillation pulse. Because the DTC is edge triggered and the oscillator is stable in either the oscillating or

## DTC uses analog, digital internal circuitry

Fig A displays the AD9500 along with the external circuitry required to configure it as a DTC. An 8-bit word sets the output voltage of the IC's internal D/A converter. The DAC's output voltage in turn establishes a threshold for the high-speed voltage comparator. You can latch the input word to the AD9500 by applying a one to the latch-enable input of the device. Alternatively, if you want to change the value of the input on the fly, hold the latch-enable input at logic zero and the latches will remain transparent.

Because the DTC controls precision delays for high-speed signals, its delay-path inputs and outputs are designed to be ECL compatible. The IC's differential-I/O structure affords maximum timing-noise immunity when you interface the chip to either 10K or 100K logic. For less demanding applications that use 10K ECL circuitry, you can use the on-chip ECL reference and operate the chip in a single-ended mode.



**Fig A—Using both analog and digital internal circuitry, the AD9500 requires only a resistor and a capacitor as external components in programmable-delay applications.  $R_{SET}$  and  $C_{SET}$  ( $C_{EXT} + C_{INT}$ ) provide a reference for the internal timing-control circuit. The ramp generated by the  $R_{SET}/C_{SET}$  time reference remains linear despite the effects of time, temperature, and supply-voltage variations.**

The DTC's time reference is RC based; it serves as the ramp generator and as a timebase for the on-chip DAC. Because the DAC's gain is proportional to the time reference, any change in the ramp's slope is compensated by the DAC's gain. This compensation reduces the effects of environmental changes on full-scale

time and timing linearity.

You determine the full-scale delay of the device through your selection of external, passive components. Although the recommended range of full-scale delays is from 2.5 nsec to 100  $\mu$ sec, you can extend delays beyond 100  $\mu$ sec if you can tolerate a degradation of the linearity and



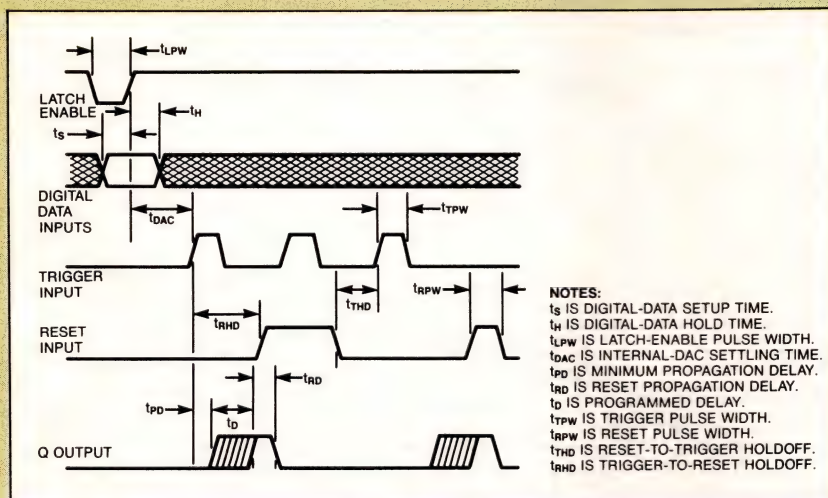
nonoscillating mode, a single pulse from IC<sub>1</sub> will start the oscillation. By grounding the trigger input on either IC<sub>2</sub> or IC<sub>3</sub>, you can stop the oscillation.

As Fig 4 shows, each DTC resets itself as it triggers the alternate DTC. The programmed delay of each device is determined by the equation given earlier. This delay, in turn, determines the output frequency of the oscillator, which is simply the reciprocal of the sum of the two propagation delays plus the two programmed delays.

When you need to measure a time delay, you can use two DTCs in conjunction with two comparators, a D-type flip-flop, and a successive-approximation register (SAR) as illustrated in Fig 5a. Flip-flop IC<sub>3</sub> serves

as a coincidence detector. The first DTC (IC<sub>1</sub>) varies the delay of the pulse applied to the D input of the flip-flop. The coincidence detector serves as a time comparator, whose function is analogous to that of a voltage comparator in a successive-approximation A/D converter.

The clock input to the flip-flop is delayed by a period equal to the unknown ECL delay. The circuit compares the first cycle of the 1-MHz clock with the unknown delay and checks to see if the delay is greater than half-scale. Then it checks for one-quarter or three-quarters scale, one-eighth or seven-eighths scale, and so on. At the end of the test process, then, the output of the SAR provides an 8-bit representation of the delay through the DUT. To measure TTL-circuit delays, you



**Fig B—Timing characteristics for the digital-to-time converter** are shown in this timing diagram. The illustration shows the relationship between the digital delay-coefficient data and the latch-enable strobe. The text delineates the limits you should observe for the various inputs, in order to obtain proper operation of the DTC.

repeatability of the delay. At the other end of the spectrum, if you choose a full-scale range of 2.5 nsec, then the smallest incremental delay available to you is 10 psec.

The maximum delay trigger rate is 100 MHz, but an offset adjustment in the device allows you to operate two DTCs in a ping-pong fashion to double the

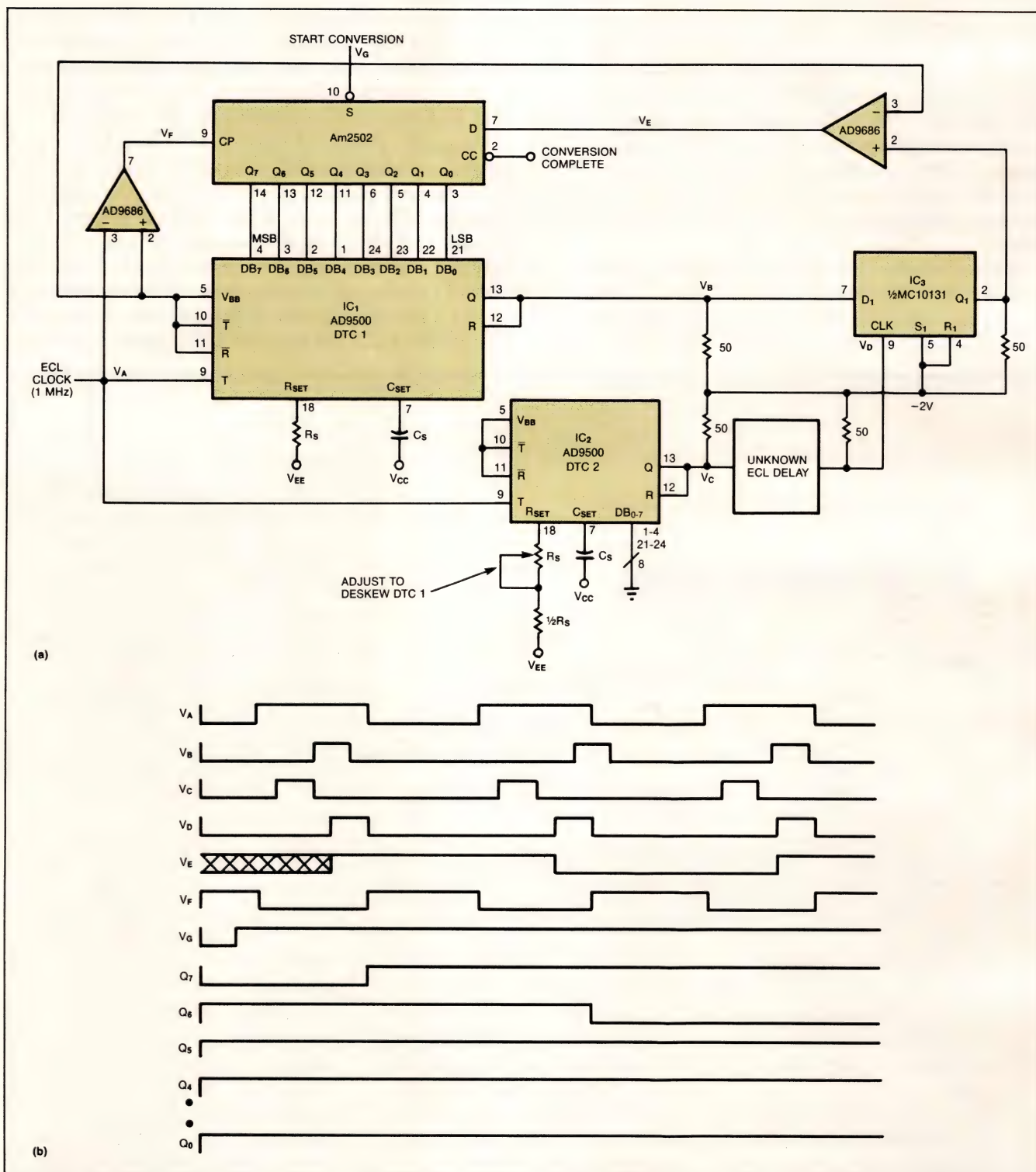
trigger rate. The IC's maximum differential nonlinearity is  $\pm \frac{1}{2}$  LSB at 25°C and  $\pm 1$  LSB over the operating-temperature range. Maximum integral nonlinearity for the device is  $\pm 1.25$  LSB for full-scale delays of 100 nsec or more over the operating-temperature range.

The timing characteristics of the AD9500 are illustrated in

**Fig B.** Lines 1 and 2 show the timing relationship between digital-delay coefficient data and the latch-enable strobe. The minimum latch-enable pulse width is 2 nsec. The data setup time for the input latch is a maximum of 2.5 nsec, and the hold time is a minimum of 4.5 nsec. You must allow at least 25 nsec from the rising edge of the latch-enable pulse before you trigger an event, otherwise the internal DAC might not have time to settle.

Lines 3, 4, and 5 of Fig B show the relationship of the output to the reset and trigger events. The total delay through the DTC is the sum of the propagation delay and the programmed delay. The propagation delay equals the delay through the differential input stage, the comparator, and the delay attributable to ignoring the first, nonlinear portion of the ramp. The last of these components increases with full-scale delay.



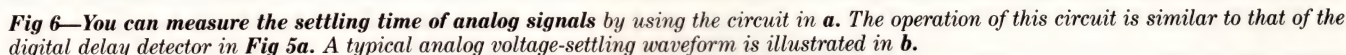


**Fig 5—Operating in similar fashion to a successive-approximation A/D converter, this circuit allows you to make precise delay measurements. The circuit in *a* handles ultrafast ECL circuitry; you can easily modify it to accommodate TTL circuits. The timing diagram in *b* illustrates the timing characteristics at various points in the circuit.**



You can use the circuit of **Fig 6a** to measure the settling time of analog signals—for example, the output of a D/A converter. The operation of this circuit is similar to the operation of the digital delay detector, but it uses a voltage-input window comparator in place

To calibrate the circuit of **Fig 5b**, you insert a shorting strap in place of the unknown-delay circuit to eliminate extraneous circuit delays and the flip-flop's setup time. To null the circuit, apply a digital code of  $00_{16}$  to  $IC_2$  and adjust potentiometer  $R_S$ . This adjustment varies the propagation delay through  $IC_2$ . The







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of the coincidence detector, and down counters in place of the SAR.

Fig 6b shows a typical analog voltage-settling waveform, as well as the output of a window comparator that uses a constant high-frequency strobe. This continuous-clock method produces ambiguous results because the signal comes into the error-band window during three clock periods. The circuit of Fig 6a, however, produces a single strobe per cycle of the analog signal and homes in on the correct measurement in the following manner.

The first DTC ( $IC_1$ ) controls the timing of the DUT switching. The second DTC ( $IC_2$ ) delays the latch-enable strobe to the high-speed window comparators. The start-conversion pulse initiates the down counters to a full-scale setting. On each cycle of the clock, the counter decrements and the strobe to the window comparator moves back closer to the time when the DUT is switched. Because the circuit starts at full-scale time, the first strobe occurs well after the DUT has settled. As successive clocks arrive, the circuit causes the strobe to back up until the DUT signal falls out of the range of the window comparator. As a result, the window comparator stops the down counter, whose output represents the settling time of the DUT.

To compensate for extraneous circuit delays, you can adjust the  $R_{SET}$  potentiometer. Insert a shorting strap in place of the DUT and change the window reference voltages  $V_A$  and  $V_B$  to  $-1.28V$  and  $-1.32V$ , respectively. Then adjust  $R_{SET}$  until you receive a zero output from the down counters. When you reset the voltages for the window around the DUT's output and the conversion takes place, the output of the down counter will represent the propagation delay plus the settling time of the DUT.

**EDN**

## Authors' biographies

Craven Hilton is a marketing engineer at Analog Devices Inc's Computer Labs Div (Greensboro, NC). An AAS graduate of the Technical College of Alamance, he's worked at ADI for 11 years. Craven's spare-time activities include golf and aquatic sports.

Jeff Barrow is a senior design engineer in charge of designing high-speed analog ICs at ADI's Computer Labs Div. A 6-year employee at ADI, he obtained a BSEE from the University of Arizona. Jeff is a member of IEEE and Tau Beta Pi. His hobbies include astronomy, mathematics, and woodworking.

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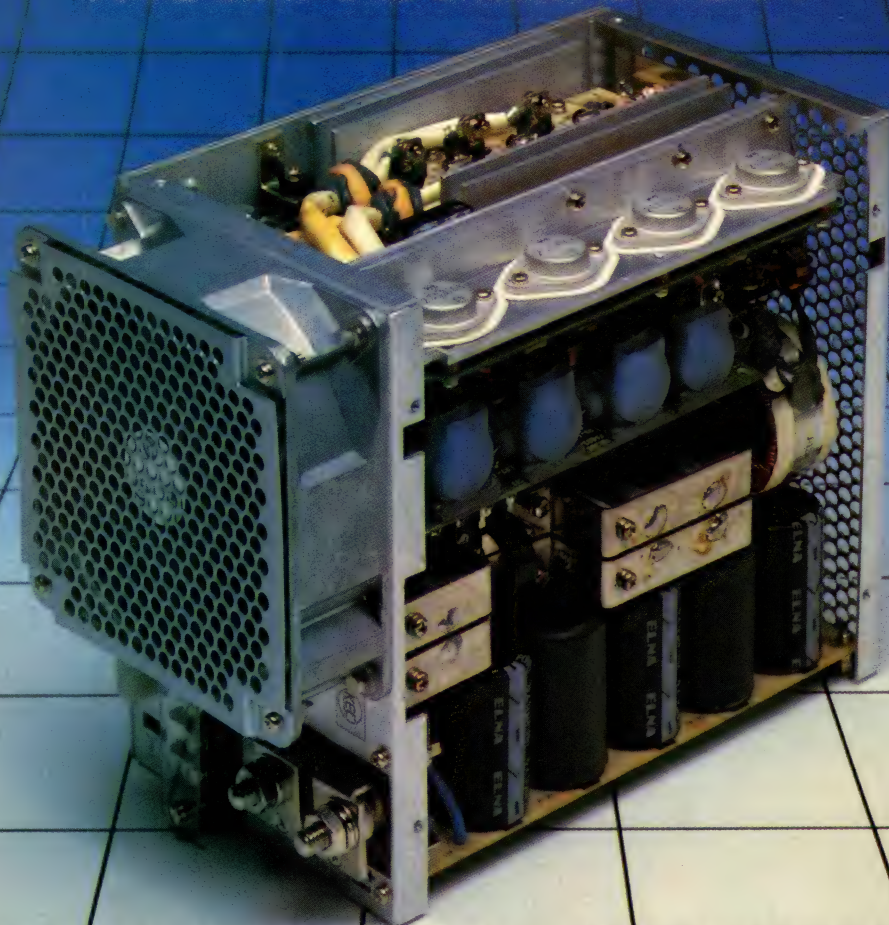
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# Precision comparators ease oscillator and data-converter design

*To simplify the task of designing high-performance circuits such as a crystal oscillator, V/F converters, A/D converters, and an ATE pin receiver, you can use a comparator that combines low bias current, high gain, high speed, and 3-state outputs.*

John Dutra and Barry Harvey, *Elantec Inc*

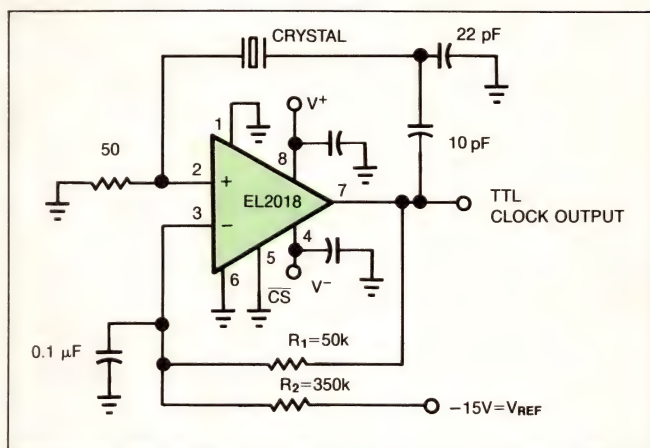
Over the years, analog designers have come to regard voltage comparators much as in the old saying about persons of the opposite gender: "You can't live with them, but you can't live without them." Comparators have a well-deserved reputation for being temperamental. For example, most comparators have a tendency to oscillate, which can cause them to yield meaningless results. One way to defend your products from the effects of such unseemly behavior is to lavish exquisite care on the comparators, both in analyzing and designing the circuits that use them and in laying out the pc boards that house them. For instance, you must drive the comparators from low-impedance sources, and you must be careful to connect bypass capacitors to the proper circuit-ground point.

To simplify the task of obtaining valid comparisons at high speed in such demanding applications as data converters and oscillators, you can employ fast, low-bias-current comparators such as the EL2018 and EL2019. These comparators don't require the lavish

care that their more temperamental counterparts do, and you can use them effectively in such applications as

- A crystal oscillator
- A pair of V/F converters, each having 0.01% of full-scale rms nonlinearity relative to the best-fit straight line, and a maximum output frequency you can set higher than 10 MHz
- Two 12-bit successive-approximation A/D converters, one of which has 1.5- $\mu$ sec total conversion time
- A high-voltage pin receiver with output multiplexing, such as those found in some automatic test systems.

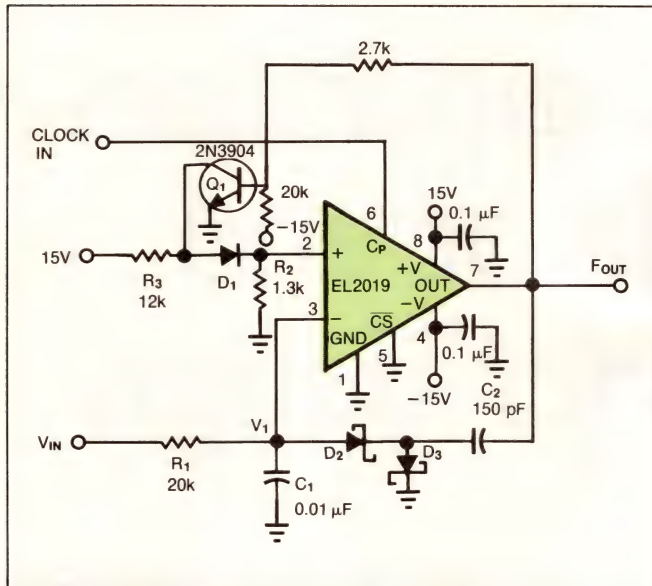
Fig 1 shows a crystal oscillator that oscillates at the crystal's 20-kHz to 20-MHz series-resonant frequency. It uses the EL2018 as a high-gain, wideband linear



**Fig 1—This crystal oscillator** uses an EL2018 as a high-gain, wideband linear amplifier.



*Most comparators have a tendency to oscillate, which can cause them to yield meaningless results.*

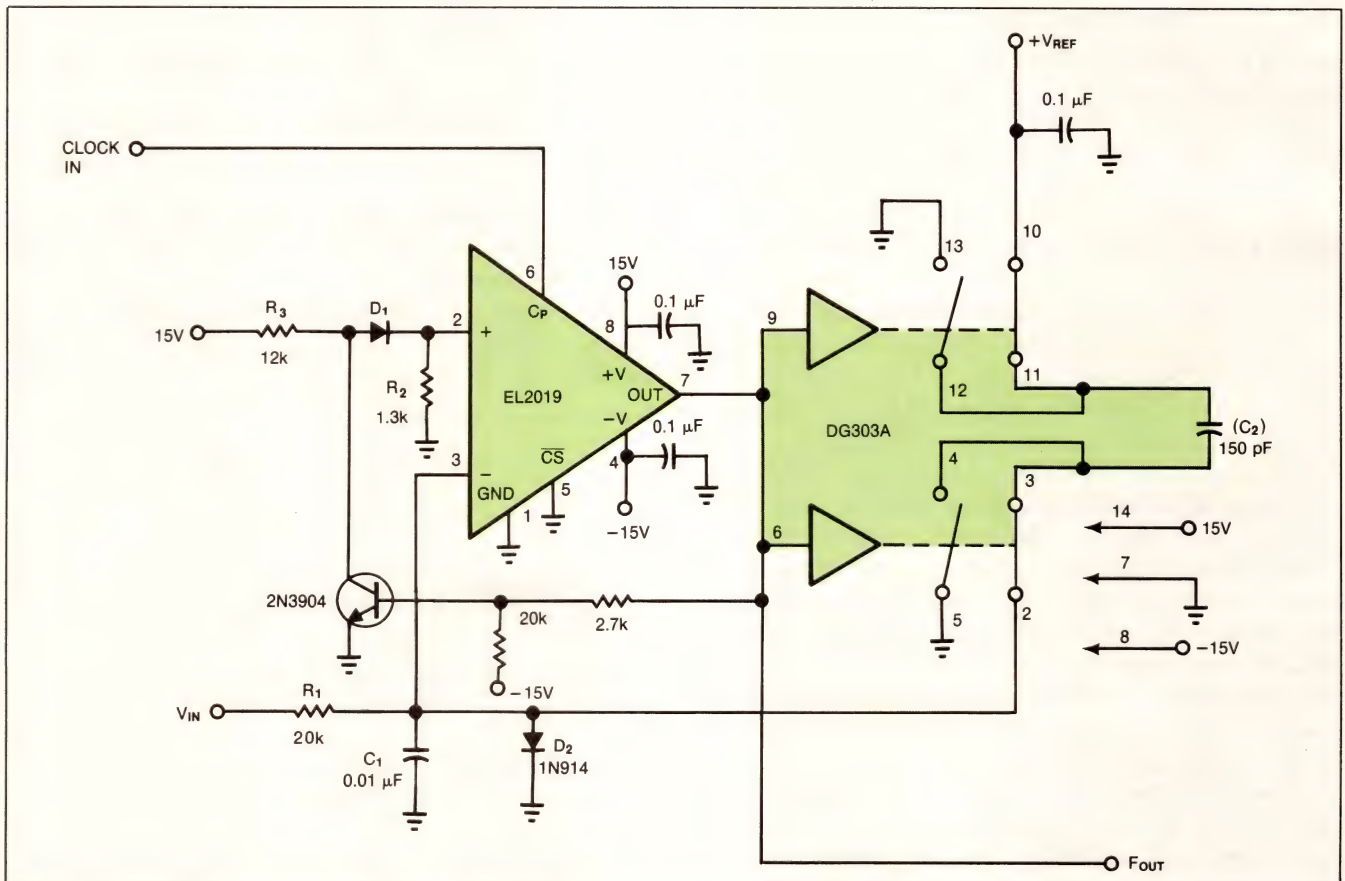


**Fig 2**—This simple V/F converter is based on the charge-balancing principle. The converter uses only one IC—an EL2019 comparator.

amplifier. Compared with simpler oscillators, this circuit provides superior immunity to load and power-supply variations. It loads the crystal with 50Ω in series with 32 pF, the preferred values for many crystals. DC feedback via  $R_1$  and  $R_2$  holds the comparator's negative input at 0V. By adjusting  $R_1$ ,  $R_2$ , or  $V_{REF}$ , you can maintain the required voltage at the comparator's negative input while causing a small variation in the output duty cycle. If you choose  $R_1$ ,  $R_2$ , or  $V_{REF}$  incorrectly, the circuit may oscillate at a subharmonic of the desired frequency.

#### V/F converter's clock input can reach 25 MHz

The circuit shown in **Fig 2** is a charge-balancing V/F converter whose output is a pulse train with a repetition rate proportional to the input voltage. Although you can control the output frequency, you can't control the shape of the output pulses. Except as a second-order effect, the frequency of the circuit's clock input does not affect the V/F-conversion scale factor; the



**Fig 3**—Adding an analog switch to Fig 2's V/F converter improves the circuit's temperature sensitivity.



clock frequency does establish an upper limit for the output pulse rate—the maximum output rate is half the clock frequency. You can use a clock whose frequency is as high as 25 MHz, and the circuit will make conversions with 0.01% of full-scale rms nonlinearity relative to the best-fit straight line.

The EL2019's output can change state only at positive-going clock edges. Normally, the comparator's output is in the high state,  $V_{OH}$ , and  $Q_1$  is saturated, so no current flows in  $D_1$ . The comparator's positive input is, therefore, essentially at ground potential, and the comparator compares the voltage at its negative input (the summing node,  $V_1$ ) to ground. If you apply a positive input, node  $V_1$  goes positive, causing the comparator output to drop to the low state,  $V_{OL}$ , at the next positive-going clock edge. The low comparator output turns  $Q_1$  off and allows the voltage at the comparator's positive input to rise to approximately 1.4V. In no event can the summing node become as positive as 1.4V, because Schottky diodes  $D_2$  and  $D_3$  will clamp it at a lower voltage. Therefore, the differential voltage at the comparator input will cause the comparator output to return to  $V_{OH}$  at the next positive-going clock edge.

Charge-balancing action occurs when the comparator output drops from  $V_{OH}$  to  $V_{OL}$ . When the comparator output is at  $V_{OH}$ ,  $C_2$  charges to  $V_{OH} - V_{D3}$ . When the comparator output drops to  $V_{OL}$ , current flows through  $C_1$ ,  $D_2$ ,  $C_2$ , and the comparator's output stage, causing charge to redistribute itself between  $C_1$  and  $C_2$ . Because  $C_1$  is much larger than  $C_2$ , the change in voltage across  $C_1$  will be much smaller than the change in voltage across  $C_2$ .

When a charge is delivered through  $D_2$ , the initial current is on the order of several milliamps, but it sags within tens of nanoseconds and continues to decay thereafter. Short clock pulses limit the time for charge to transfer fully to  $C_1$ , thus making the scale factor slightly clock-rate dependent at high frequencies.

#### Diode drops cause temperature sensitivity

The output frequency is given by the equation:

$$F = V_{IN} \div [R_1 C_2 (V_{OH} - V_{OL} - V_{D3} - V_{D2})]$$

where  $R$  is in ohms,  $C$  is in farads, and  $F$  is in hertz. Note that although  $C_1$  doesn't appear in the equation, you don't have complete freedom in selecting it.  $C_1$  must be much larger than  $C_2$ , but it must not be so large that the change in voltage across  $C_1$  during a single clock cycle (which is approximately equal to the change in

voltage across  $C_2$  multiplied by  $C_2/C_1$ ) is small compared to the comparator's noise level. The tradeoff in  $C_1$ 's value is that it should not be so large that it takes too much time to count and average the output pulses, but it should not be so small that it causes excessive output frequency jitter. If the input signal is so large (or  $C_1$  is so small) that in a single clock period  $C_1$  charges to the point where  $D_2$  and  $D_3$  conduct, the output will not latch. The pulse rate will rise to its maximum possible value—half the clock frequency.

The clock frequency can be as high as 25 MHz for V/F linearity of 0.01% of full scale. The voltage-to-frequency conversion remains linear for output frequencies about as high as 45% of the clock frequency. The circuit's input-offset voltage is predominantly that of the EL2019. The V/F scale factor is reasonably constant over temperature, because of the constant logic levels at the EL2019 output and the low voltage drop across the Schottky diodes,  $D_2$  and  $D_3$ . These diodes are the major source of calibration sensitivity to  $f_{CLOCK}$ .

#### Use analog switch to improve stability

Fig 3 shows an improved version of the V/F-converter circuit. In Fig 3's circuit, a DG303A analog switch is used as a dpdt switch to connect  $C_2$  either from  $V_{REF}$  to ground or from ground to the summing node. For Fig 3,

$$SF \approx V_{REF} \times R_1 \times C_2.$$

Charge transfer between the drive and signal portions of the analog switch is the major error source in this circuit. Note that Fig 3's scale-factor expression, unlike that of Fig 1, contains no temperature-dependent terms.

Fig 4a shows the schematic of a 12-bit successive-approximation A/D converter. The 25HCT04 is faster than the traditional 2504 successive-approximation register, and the AD565A D/A converter provides a typical 150-nsec settling time at the summing junction. The EL2018 provides a 20-nsec typ response time and draws only 0.2 LSB of bias current. The required output swing of 0.8 to 2.0V, divided by the voltage gain of 40,000, yields an input uncertainty of only 0.02 LSB, which is less than the system noise and the comparator's thermal noise. A breadboard of this circuit had only about 0.1 LSB of noise, peak to peak.

Fig 4b shows that the maximum delay times of the components yield a 4- $\mu$ sec worst-case conversion time. In practice, the breadboard version of this circuit achieves its specified accuracy at a conversion time as



*One way to defend your circuits from comparators' unseemly behavior is to lavish exquisite care on the comparators.*

short as 2.5  $\mu\text{sec}$  with no resistance at the summing junction, and 1.8  $\mu\text{sec}$  with 3.9  $k\Omega$  from summing junction to ground; the circuit's noise is still acceptable.

Star grounds don't work at these speeds, so the breadboard employs a copper ground plane with all wires draped physically close to the plane. The analog

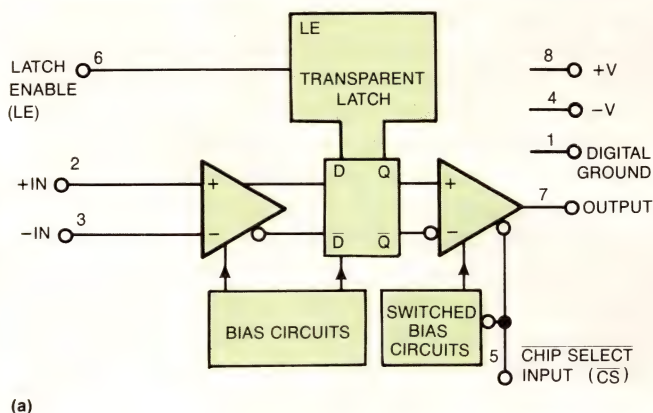
## Flip-flop succeeds where latch often failed

You can model the EL2018 as an input comparator followed by a simple logic latch that's followed in turn by an output 3-state TTL buffer (Fig A). The EL2019 replaces the latch with a full master/slave flip-flop—the input and output stages are the same as those in the EL2018 (Fig B).

High-speed comparators have traditionally had output latches. The latches aren't just for data storage; their purpose is to help suppress oscillations. Clearly, when a comparator's latch is set to latch mode, no coupling from output to input can ever cause sustained oscillation. Generally, you need to hold the latch in transparent mode for only a short time (in comparison with the time it would take a signal to propagate through the comparator IC.) Thus, a quick pulse on the latch-enable pin allows the latch to capture new data without connecting the output to the input long enough for the comparator to build up an oscillation.

A significant problem with the latch enable is that it can influence the comparator's decision no matter what you do to prevent such influence—it is, after all, an analog input to an analog circuit element. Even though you just want it to strobe the output, it does more—all too often it affects the accuracy of the comparisons.

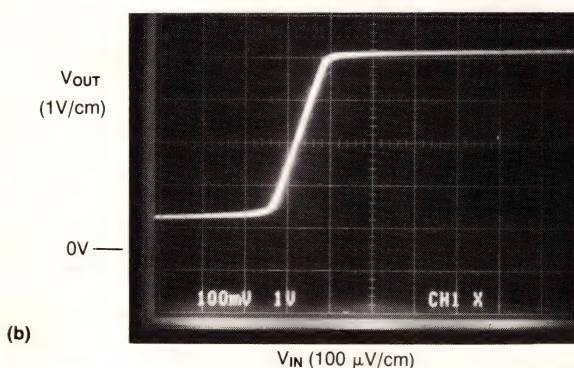
A master/slave flip-flop, as in the EL2019, solves the problem



(a)

FUNCTION TABLE

INPUTS (TIME N-1)				INTERNAL Q	NOTES	OUTPUT
+IN	-IN	CS	LE			
+	-	L	L	H	NORMAL COMPARATOR OPERATION	H
-	+	L	L	L		L
+	-	H	L	H	INTERNAL NORMAL COMPARATOR OPERATION OUTPUT POWER-DOWN MODE	HIGH Z
-	+	H	L	L		HIGH Z
X	X	L	H	$Q_{N-1}$	DATA RETAINED IN LATCH DATA RETAINED IN LATCH POWER-DOWN MODE	$Q_{N-1}$
X	X	H	H	$Q_{N-1}$		HIGH Z



(b)

**Fig A—The EL2018 comparator (a) has three major sections—an input comparator followed by a simple logic latch, which is followed in turn by an output 3-state TTL buffer. The transfer function of the comparator (b) shows that an input voltage change of approximately 100  $\mu\text{V}$  causes an output change of approximately 4V, which is a voltage gain of approximately 40,000.**



circuitry is located in one compact region away from all digital lines, and the comparator output is routed with rigid coaxial cable to prevent noise feedback. During

the conversion, the current drawn from the signal source by the A/D input varies rapidly. To prevent these current fluctuations from destroying the conver-

altogether. At no condition of the clock input can an analog signal pass through the device. Rather, a comparison of the inputs propagates to the output only after a positive-going clock edge; the analog input is completely quantized as the digital output.

The master/slave configuration offers other benefits as well. Because the analog input requires about 4 nsec of input setup time before the clock edge, the clock edge itself can't influence the analog comparison. That is, the clock edge has a zero setup time and the comparator ignores it because it doesn't meet the setup requirement. Latched comparators, in contrast, allow both clock edges to influence the analog output.

The master/slave flip-flop gives the comparator virtually infinite gain; that is, a very small input can determine a full logic-output swing. In fact, the small input noise of the EL2019 (5 nV/ $\sqrt{\text{Hz}}$  yields 30  $\mu\text{V}$  rms thermal noise) is greater than any measured gain error. You can say that the EL2019 has only offset and thermal noise errors, which is a boon to A/D conversion. Finally, in many comparator applications, such as delta modulators, an external flip-flop follows the comparator; in such circuits, the EL2019 saves external components.

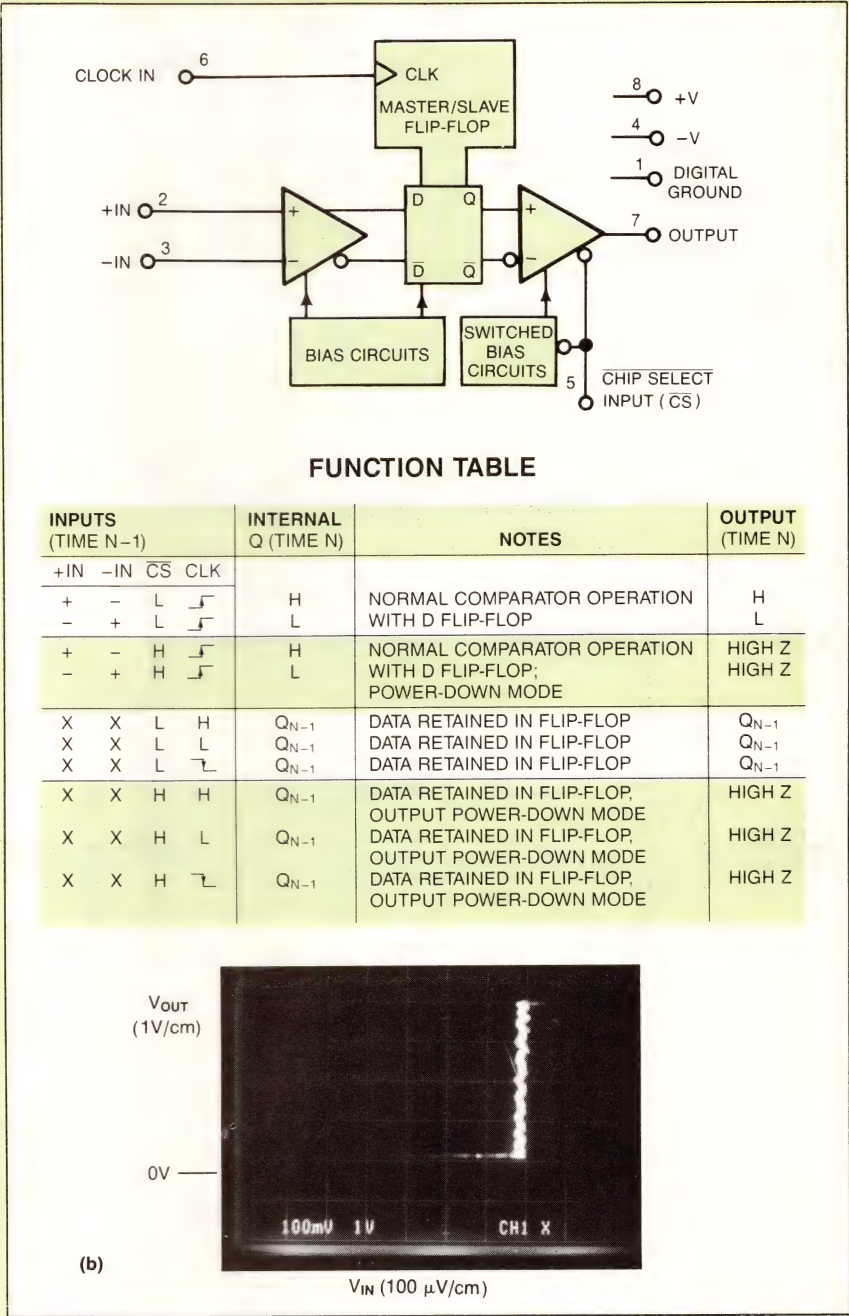
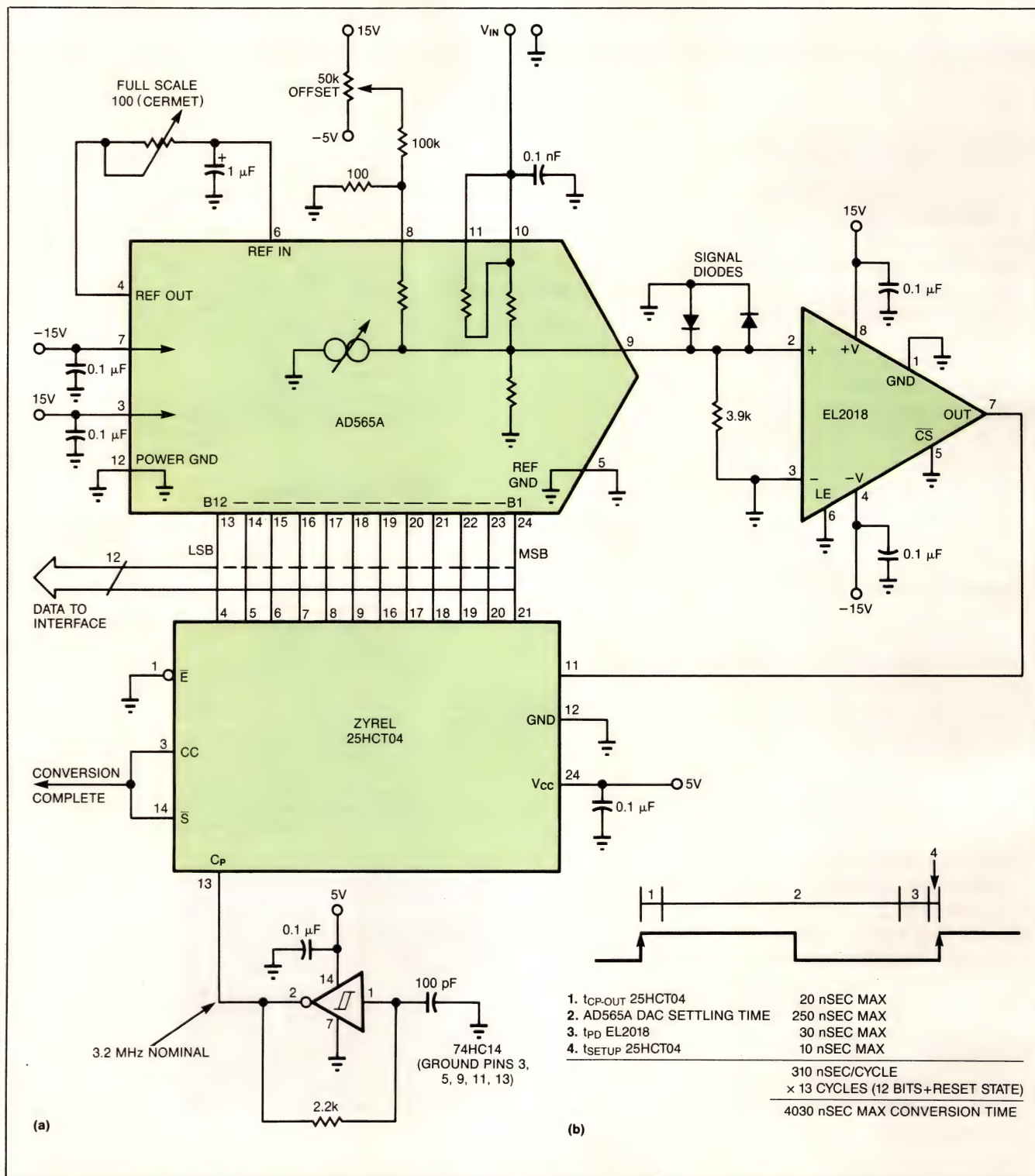


Fig B—The EL2019 (a) is similar to the EL2018, except that it replaces the EL2018's latch with a full master/slave flip-flop. The transfer function of the EL2019 (b) exhibits essentially infinite voltage gain because of the EL2019's master/slave flip-flop.



Fast, low-bias-current comparators can simplify the task of obtaining valid comparisons at high speed in demanding applications.



**Fig 4—A 12-bit successive-approximation A/D converter (a) that uses the EL2018 and an AD565 D/A converter achieves a 4- $\mu$ sec total conversion time. The timing diagram for this circuit (b) shows that D/A-converter settling consumes approximately 80% of the total time.**



The A/D converter of Fig 5a uses the TRW

The A/D converter of Fig 5a uses the TRW



The A/D converter of Fig 5a uses the TRW



---

*You can use fast, low-bias-current comparators in such applications as a crystal oscillator, data converters, and a high-voltage pin receiver.*

---

1V, the LSB value is 244  $\mu$ V, which is clearly a very small signal for the comparator to resolve. When an EL2018 with its latch permanently enabled is substituted for the EL2019 in this design, the small signals drive the EL2018 output into its linear operating output range, and code feedback causes errors of several LSBs.

You can overcome these difficulties by using a comparator, such as the EL2019, that has virtually infinite gain. Because the output of the EL2019 can change only after the clock edge, no linear feedback or uncertainties exist. In the EL2019 version of the circuit, the conversion accuracies are limited by the DAC's linearity and

the noise of the EL2019's front end. Further, because of the EL2019's master/slave flip-flop, the circuit's timing relationships are precisely defined and synchronous clock noise is eliminated (see **box**, "Flip-flop succeeds where latch often failed").

The clock of the 1.5- $\mu$ sec A/D converter has an unusual duty cycle. You can see the need for this duty cycle by referring to **Fig 5b**, which shows the timing relationships in the 1.5- $\mu$ sec A/D converter. Note that  $R_X$  and  $R_Y$  independently adjust the high and low times of the clock signal. You could improve this A/D converter's speed by another 20% or so by using a "speed-up clock" approach (**Refs 1 and 2**). In systems that provide

---

## Comparators combine high gain, low bias current

To see where the EL2018 and EL2019 fit into the spectrum of available IC comparators, you can examine their key specifications beside those of two industry-workhorse comparator families, the general-purpose 111/311 and the high-speed 685. The EL2018 and EL2019 offer significant improvements over the general-purpose, 111/311-class comparators. And although the EL2018 and EL2019 appear to be slower than the high-speed, 685-class devices, they're actually faster in many applications.

The EL2018 and 2019 offer a combination of high gain and low bias current that you can't obtain from the high-speed 685-class devices without adding large numbers of external components. Besides raising costs and consuming pc-board space, the added components slow the 685-class comparators, in most cases, to a speed no greater than that of the EL2018/2019.

For example, the EL2018 and -2019 spec a typical response time of 20 nsec, which is approximately 10 times as fast as the

311's response time, but only about  $\frac{1}{2}$  to  $\frac{1}{4}$  the speed of most 685-class devices.

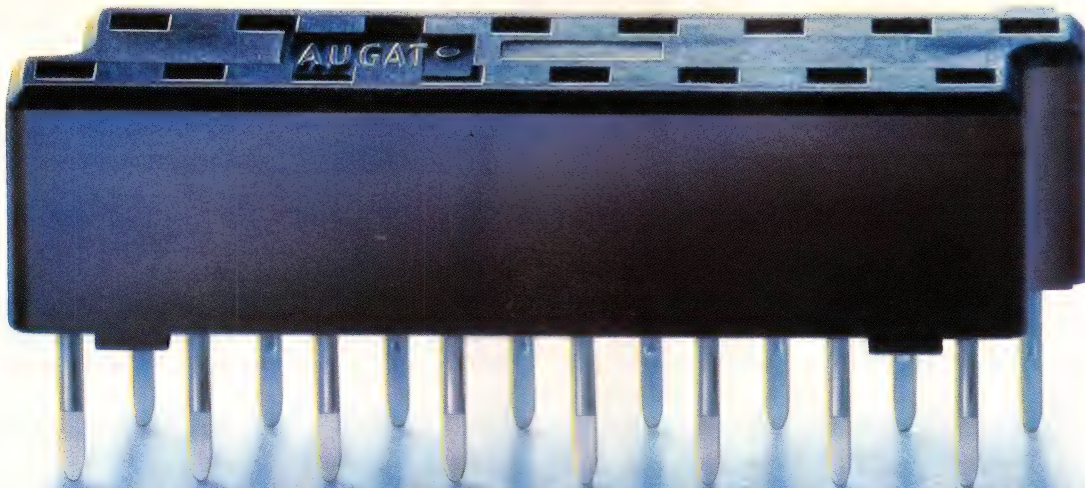
An ideal comparator would have an input bias current of zero; the EL2018/2019's typical input bias current (at room temperature) is 100 nA—40% that of 111/311-class devices and no more than 0.5% to 1% that of 685-class parts. An ideal comparator would have infinite voltage gain, something the EL2019 achieves, in effect, by using a master/slave output flip-flop. The gain of the EL2018, which has a conventional output latch, is comparable to the gain of the 111/311 and is more than 10 times as great as that of 685-class comparators.

The outputs of the EL2018 and EL2019 retain full TTL compatibility when you operate the comparators from supply voltages anywhere in the  $\pm 4.5$  to  $\pm 16.5$ V operating range. If the positive supply voltage is 12V or greater, the devices produce output levels compatible with the inputs of CMOS logic devices operating from a 5V sup-

ply. Each comparator has a chip-select input, which you can use to force its output to a high-impedance state without affecting the input circuits. When its output is disabled, a comparator's power dissipation is halved. You can safely parallel the outputs of many comparators as long as you enable only one device at a time and allow it sufficient turn-off time before you enable the next.

Regardless of the supply voltages, the EL2018 and EL2019 operate normally when their inputs are 3V smaller in magnitude (2V typ) than the supply voltages. Although many comparators malfunction or even suffer damage when you apply large differential inputs, the EL2018 and EL2019 continue to perform within their specifications after you apply such signals. The only requirement is that you maintain each input within the specified operating range; for example, with  $\pm 15$ V supplies, the units will correctly respond to a 5-mV input-voltage difference immediately after you remove a 24V (26V typ) differential input.





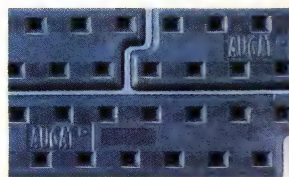
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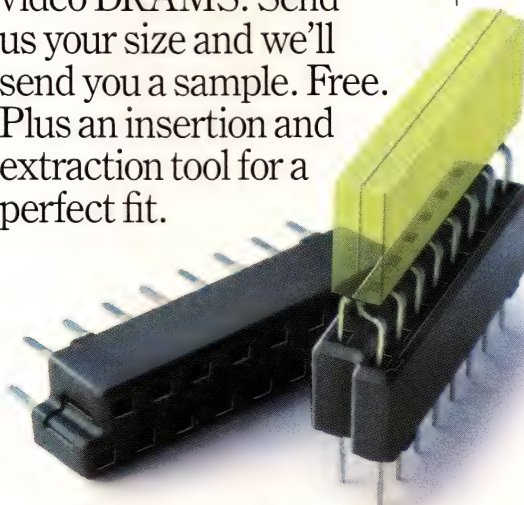
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*A crystal oscillator that uses the EL2018 comparator as a high-gain, wideband linear amplifier can provide superior immunity to load and supply variations.*

higher analog input voltages, the comparator would let you extend the circuit's resolution to 16 bits.

Some unusual properties of the EL2018 and EL2019 can prove useful in such applications as a pin receiver for automatic test equipment (Fig 6). For example, the comparators' input stages can handle signals as large as  $\pm 12\text{V}$  in any combination, and the comparators have 3-state output capability, which can halve the device's power dissipation while maintaining input circuits in the active mode. (See **box**, "Comparators combine high gain, low bias current.")

In Fig 7's circuit, when  $\overline{\text{CS}}$  (pin 5) is at  $V_{IH}$ , the device's output impedance is high and the supply current is 50% of its active-output value, yet the input stage and latch continue to function, allowing you to clock multiple comparators simultaneously and read the outputs sequentially. The ability to capture data on

many lines at a time and read it back sequentially is useful in large test systems, which may have as many as 1000 comparators, only 10% of which are active at one time.

The  $50\Omega$  resistors in series with the outputs of each comparator limit the fault currents, which can flow because the output stage of the comparator turns on faster than it turns off. Without the current-limiting resistors, the aforementioned output-stage characteristic could cause momentary short circuits across the comparator's power-supply lines. You can clock the input latch at speeds as high as 30 MHz, and you can scan the outputs at a 5-MHz rate.

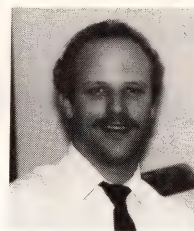
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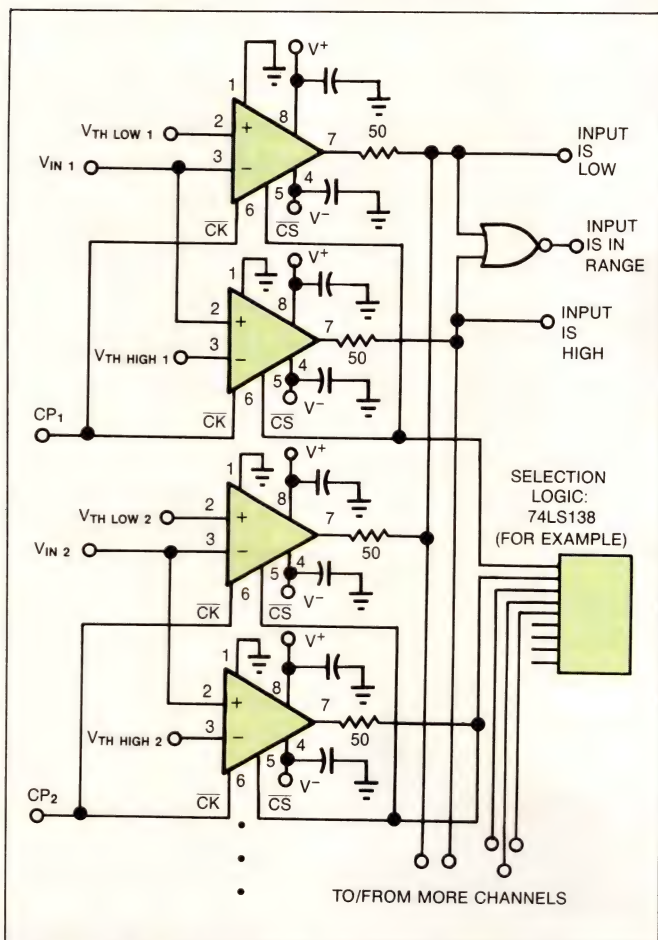
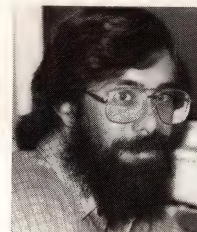
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## Authors' biographies

Jon Dutra is currently applications manager at Elantec (Milpitas, CA). He holds a BSEE from California State Polytechnic University at San Luis Obispo, an MSEE from the University of California at Davis, and an MBA from the University of California at Berkeley. In his spare time he enjoys amateur radio, flying, and teaching his new son old tricks.



Barry Harvey is a senior design engineer for high-speed analog IC's at Elantec. He previously worked for Precision Monolithics, Siliconix, and AMD. He holds an MSEE from Stanford University and has been granted two patents. In his spare time, he enjoys running, playing guitar and mandolin, and programming his personal computer.

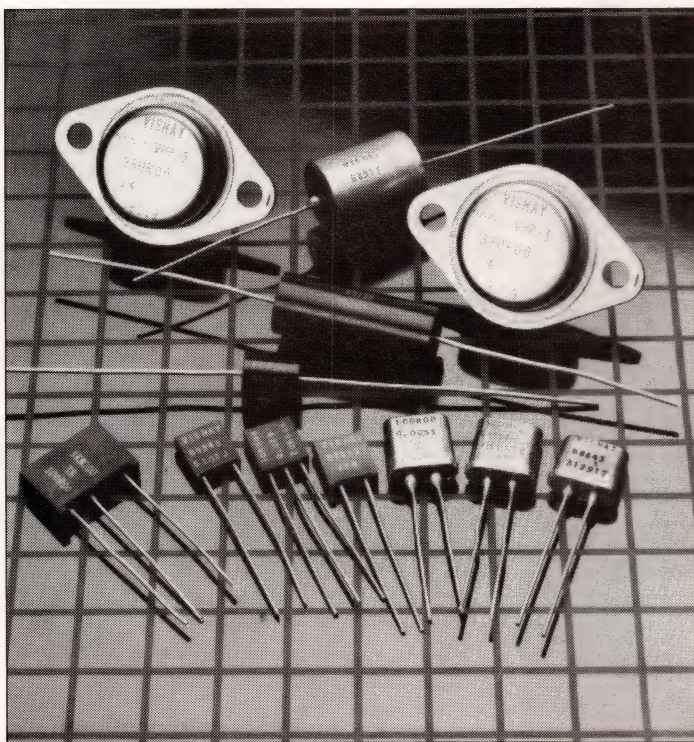


**Fig 6—This multiplexed ATE pin receiver** takes advantage of the comparators' 3-state outputs to capture the states of many analog signals simultaneously and read them back sequentially.

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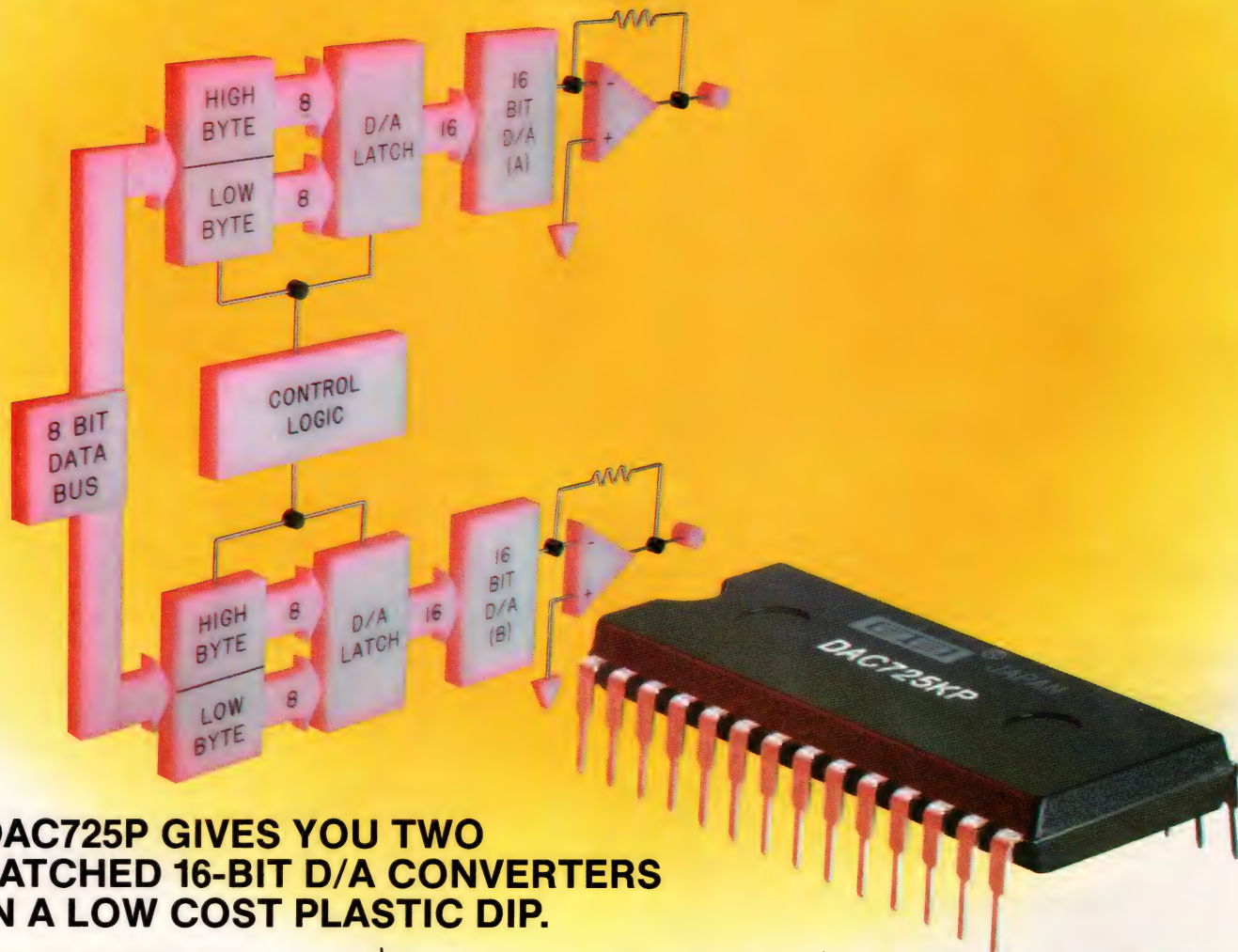


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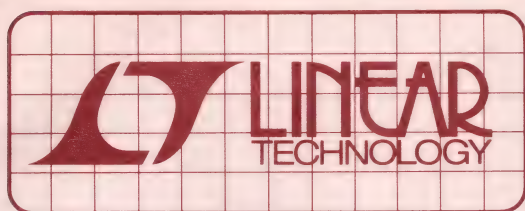
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# DESIGN NOTES

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## DC Accurate Filter Eases PLL Design

Nello Sevastopoulos

Philip Karantzalis

The LTC1062 is a versatile, DC accurate, instrumentation lowpass filter with gain and phase that closely approximate a 5th order Butterworth filter. The LTC1062 is quite different from presently available lowpass switched capacitor filters because it uses an external (R, C) to isolate the IC from the input signal DC path, thus providing DC accuracy. The DC accurate output, pin 7 of Figure 1, is buffered by an internal op amp from the switched capacitor network. The output of the switched capacitor network drives the bottom of C1. The input and output appear across an external resistor and, the IC part of the overall filter handles only the AC path of the signal. A buffered output is also provided (Figure 1) and its maximum guaranteed offset voltage over temperature is 20mV. Typically the buffered output offset is 0-5mV and drift is  $1\mu\text{V}/^\circ\text{C}$ . The use of an input (R, C) also provides other advantages, such as lower noise and antialiasing.

With commercially available PLLs, the loop filter is designed by the user to optimize the loop performance. For a variety of applications, a 1st or 2nd order lowpass passive or active R, C filter will do the job. When minimum output jitter and good transient response are required simultaneously, the design of the loop filter becomes more sophisticated. For instance, a fast transient response implies wide filter bandwidth and a reduced VCO output jitter implies minimum ripple at the VCO input. This is achieved by high outband attenuation of the lowpass filter. The LTC1062 provides the above requirements as well as economy and cutoff frequency programmability to be used advantageously in PLL designs.

The circuit of Figure 2 illustrates the use of the LTC1062 as a loop filter. The power supplies for the circuit are a single 5V

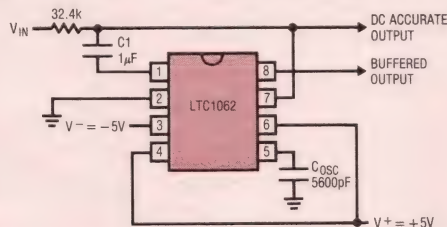


Figure 1. 8Hz 5th Order Butterworth Lowpass Filter

for the PLL and  $\pm 5\text{V}$  for the LTC1062. The CMOS PLL is a CD4046B. The LTC1062 can also be used with a single 5V with some additional level shifting (see AN20). Phase detector #2 drives a diode-resistor limiter combination to make the voltage at input R of the LTC1062 swing from one diode above ground to one diode below the 5V supply. Additionally, the two 5k resistors establish a maximum AC impedance to keep the LTC1062 in its operating region and to bias the VCO input at its mid point when phase detector #2 switches into a three-state mode.

An empirical design procedure for input frequencies less than 5kHz ( $f_{IN} \leq 5\text{kHz}$ , Figure 2) is illustrated below:

- Given the minimum input frequency value, the cutoff frequency,  $f_c$ , of the LTC1062 should be chosen as:

$$1/6 (f_{IN(MIN)}) \leq f_c \leq 1/4 (f_{IN(MIN)})$$

The internal (or external) clock frequency of the LTC1062 should be 150 to 250 times the desired cutoff frequency,  $f_c$ .

- The capacitor  $C_{OSC}$  setting the LTC1062's internal oscillator should be chosen by:

$$C_{OSC} = \left( \frac{130\text{kHz}}{250 \times f_c} - 1 \right) \times 33\text{pF}$$

By further decreasing the value of  $C_{OSC}$ , the internal clock frequency of the LTC1062 increases and the damping of the loop also increases.

- By letting the value of  $C = 0.047\mu\text{F}$ , the LTC1062 input resistor R should be:

$$R = \frac{5500\text{k}\Omega}{f_c (\text{Hz})}$$

Note: For this application, the loop filter is not required to be maximum flat and, therefore, the (R, C) values of the LTC1062 can be within  $\pm 5\%$  tolerance.

To illustrate the performance difference between a lowpass passive R, C loop filter and the LTC1062, the circuit of Figure 2 was tested for a PLL with a  $60\text{Hz} \pm 10\%$  input fre-



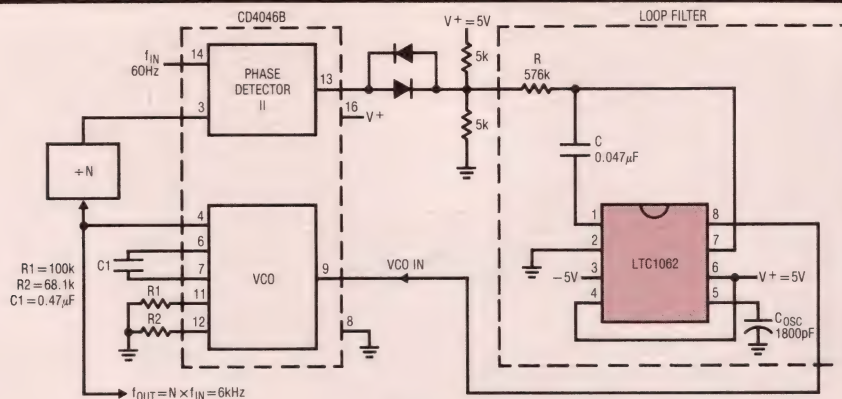
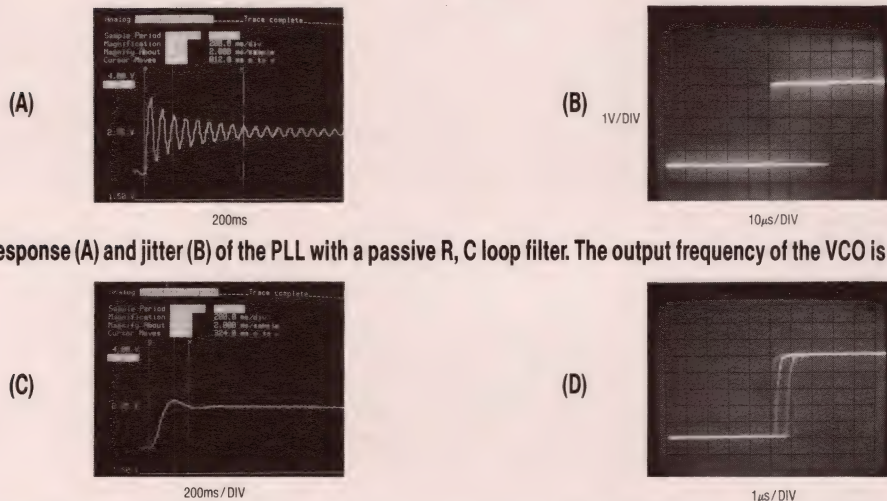


Figure 2



Transient response (A) and jitter (B) of the PLL with a passive R, C loop filter. The output frequency of the VCO is 6kHz and the  $\div N = 100$ .

Transient response (C) and jitter (D) of the PLL with the LTC1062 used as a loop filter. The VCO output frequency is 6kHz and the  $\div N = 100$ . The jitter is reduced to the internal jitter of the VCO.

Figure 3

quency range and with  $\div N = 100$ . Then, the PLL's VCO output could be used to drive the clock input of a precision switched capacitor filter, such as an LTC1060A set up in a 100:1 clock to center ratio, and configured as a 60Hz sharp notch or bandpass filter. Figure 3A shows the transient response of the loop when a passive R,C loop filter, Figure 4, is used. The input frequency is shifted from 54Hz to 60Hz and the loop takes 820ms to settle within 5% of its steady state value. The corner frequency of the R, C passive filter is 22Hz. The natural frequency of the loop is approximately 10Hz and the damping factor less than 0.1. Figure 3B shows the jitter at the VCO output under the above conditions. A  $30\mu\text{s}$  jitter with  $f_{OUT} = 6\text{kHz}$  corresponds to 18% instantaneous frequency inaccuracy. This makes the PLL VCO output unusable as a

clock generator for a tracking switched capacitor filter. A small improvement in the VCO output jitter could be achieved by further decreasing the filter's cutoff frequency; this, however, would further penalize the circuit's settling time.

Figures 3C and 3D show the PLL performance when an LTC1062 is used as a loop filter. The corner frequency  $f_c$  of the LTC1062 was set at 9.5Hz ( $\approx 1/6 f_{IN}$ ) and its internal clock was set for 2.4kHz ( $\approx 252 \times f_c$ ). The settling time of the loop was 320ms and the damping factor was optimally set to 0.7. The  $1\mu\text{s}$  VCO output jitter,  $f_{OUT} = 6\text{kHz}$ , was measured over 5 periods and it is attributed to the inherited jitter of the VCO internal circuitry. With the LTC1062 used as a loop filter, the circuit's jitter corresponds to 0.12% frequency error. This is quite adequate to drive the clock input of 0.3% accurate switched capacitor filters, such as LTC1059A or LTC1060A.

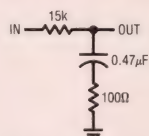


Figure 4. Lowpass R, C Filters used for PLL Example

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# DESIGN IDEAS

EDITED BY TARLTON FLEMING

## Comparator circuit monitors window events

T G Barnett

London Hospital Medical College, London, UK

The Fig 1 circuit is a window comparator that generates an output pulse for each event that occurs within a specified window. That is, each output pulse signifies an input voltage pulse or level change that exceeds  $V_{REF\ LOW}$  but not  $V_{REF\ HIGH}$ .

The monostable multivibrators  $IC_{2A}$  and  $IC_{2B}$  produce a 10- $\mu$ sec pulse at their Q output in response to a rising edge at their A input (Fig 2). Comparator  $IC_{1B}$  produces a rising edge when the input exceeds  $V_{REF\ LOW}$ , and comparator  $IC_{2A}$  produces a rising edge when the input exceeds  $V_{REF\ HIGH}$ .

NOR gates  $IC_{3A}$  and  $IC_{3B}$  form a bistable latch whose Q output (when low) disables  $IC_4$ .  $IC_4$  (unless disabled) produces output pulses in response to falling edges at the  $IC_{1B}$  comparator output. You set the width of these pulses by selecting the  $C_3$  capacitor value. As shown, the circuit can handle an input waveform containing 0 to 2V amplitudes and 10-Hz to 10-kHz frequency components. The supply voltage is 5V.

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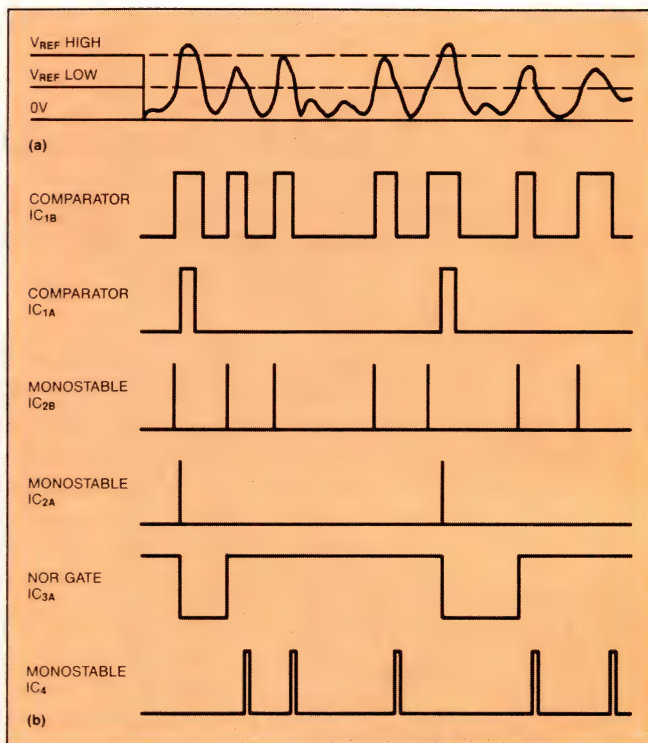


Fig 2—In response to an input signal (a), the Fig 1 circuit's ICs produce outputs (b) that depend on the input's relationship to high and low reference voltages.

To Vote For This Design, Circle No 749

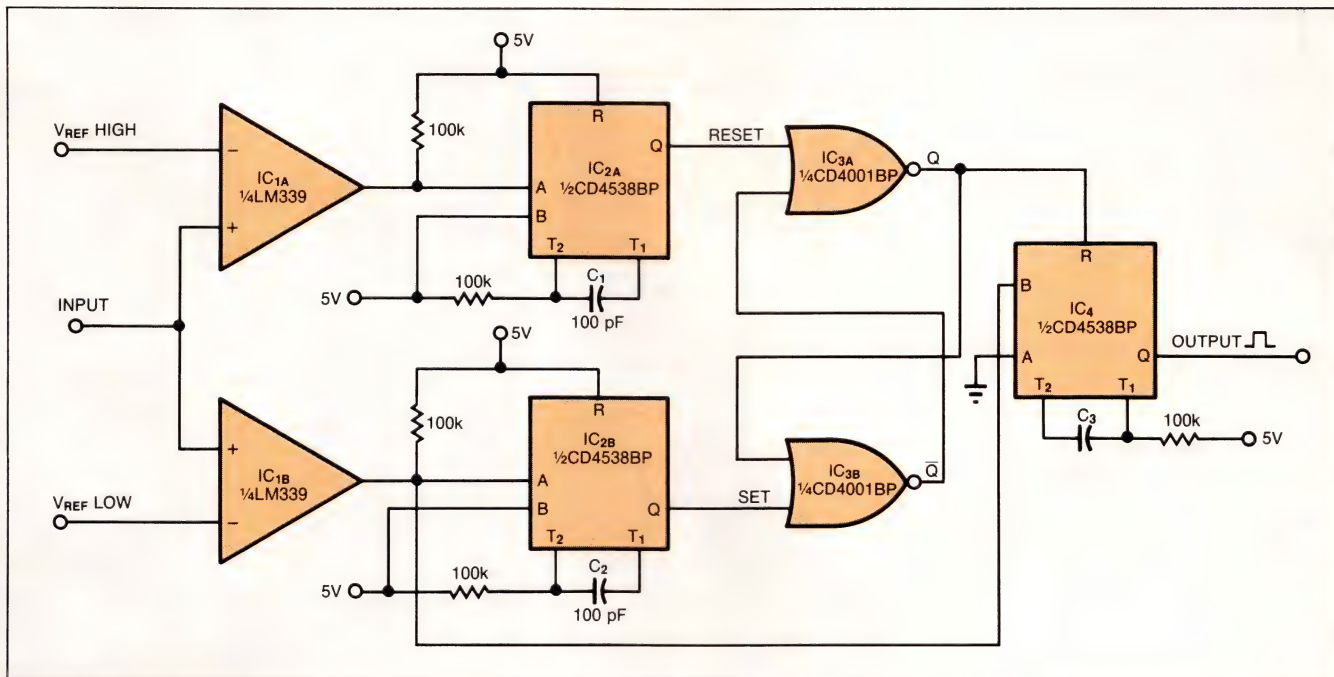


Fig 1—This window comparator can serve as a pulse-height discriminator—the circuit generates an output pulse for each input-pulse height between  $V_{REF\ LOW}$  and  $V_{REF\ HIGH}$ .



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## MOSFETs provide low-loss rectification

William Chater

The Aerospace Corp, Los Angeles, CA

Rectifiers strongly affect the efficiency of a low-voltage power supply. Silicon diodes, for example, carry a 0.7V forward-voltage penalty. You can avoid much of the power dissipation and heat burden associated with diode rectifiers by using the high-efficiency MOSFET rectifiers shown in Fig 1. This approach is especially useful in vacuum work, where the lack of convection cooling limits the allowable power dissipation.

The secondary of the transformer shown in Fig 1 maintains opposite-polarity  $V_{DS}$  voltages across the MOSFETs  $Q_1$  and  $Q_2$ ; it reverses these polarities once per input cycle. With each change of polarity, the secondary voltage also toggles the MOSFETs' on/off states by causing the output of each comparator (IC<sub>1A</sub> and IC<sub>1B</sub>) to switch between the comparators' supply rails. As a result, a unidirectional and nearly constant current flows from the transformer's center tap through the load and back through each MOSFET in turn.

In Fig 2, note how an IRFF110 MOSFET's familiar first-quadrant curves extend into the less familiar third quadrant. In particular, note that the channel is off for  $V_{GS}$  less than 3V (first quadrant) and fully on for  $V_{GS}$  in the 4 to 6V range (third quadrant). Thus, by switching

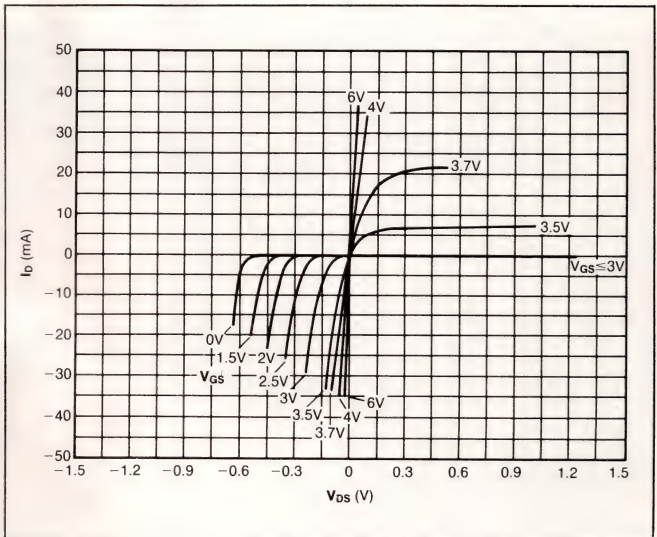


Fig 2—These characteristic curves for an IRFF110 MOSFET show how it can simulate a nearly ideal diode when you simultaneously switch its  $V_{DS}$  and  $V_{GS}$  voltages.

the  $V_{GS}$  level you can simulate a diode with very low on-resistance and low forward bias. What's more, this approach avoids activating the MOSFET's parasitic diodes, which usually prevent the application of MOSFETs as rectifiers.

In the circuit shown in Fig 1, the comparators' open-collector outputs provide a rapid transition to the

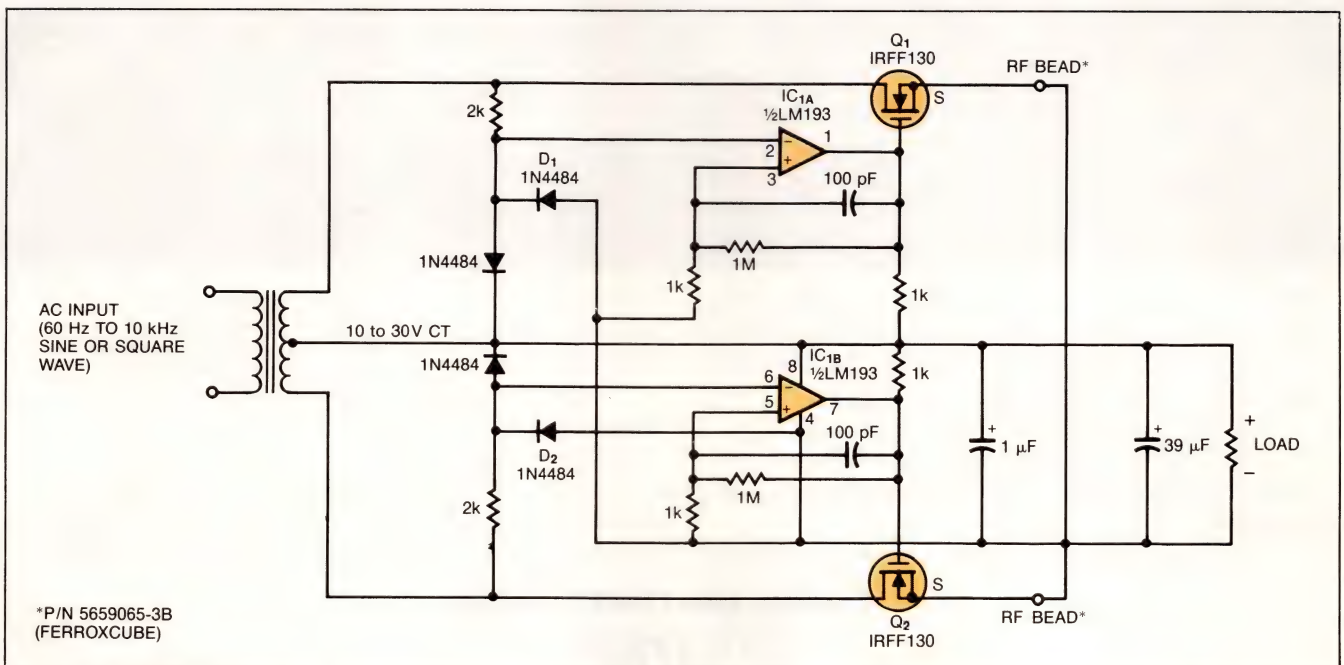


Fig 1—Using MOSFET switches in place of diode rectifiers, this full-wave rectifier circuit produces a 5V, 1A output at 97% efficiency.



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CIRCLE NO 193



# DESIGN IDEAS

low state, but the 1-k $\Omega$  pullup resistors produce a slower transition to the high level. The MOSFETs thus avoid conduction overlap by turning off rapidly and turning on slowly. Diodes D<sub>1</sub> and D<sub>2</sub> offer protection by clamping the comparators' inverting-input voltages with respect to the negative supply voltage (pin 4). These diodes are normally superfluous, however, because the MOSFETs' low forward drop won't allow the diodes to turn on.

Using a square-wave input, this circuit can produce a 5V, 1A output with 97% efficiency (resistive losses are 60 mW, and each transistor dissipates another 60 mW). For even lower losses, you can parallel two MOSFETs

for each switch. Using diode rectifiers, the efficiency would be about 90%. The use of a sine-wave input also lowers the circuit efficiency but not to the level of a diode-rectifier version: The duty cycle of the switches in Fig 1 goes from almost 50% with a square-wave input to about 20% with a sine-wave input. Consequently, the switches deliver greater-amplitude current pulses to the load filter, which increases the power dissipation.

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## Temperature sensor has 4- to 20-mA output

Art Kapoor

Precision Monolithics Inc, Santa Clara, CA

The Fig 1 circuit's current-transmitter output (4 to 20 mA) is proportional to temperature. The transmitter accepts an 8 to 40V supply voltage, exhibits a PSR better than 0.0003%/V, and provides  $\pm 1\%$  accuracy over the  $-50$  to  $+150^\circ\text{C}$  temperature range after calibration. IC<sub>1</sub>'s temperature-proportional output  $V_{\text{TEMP}}$  lets the chip serve as a temperature sensor as well as a 2.5V reference.  $V_{\text{TEMP}}$  equals 0.55V at  $25^\circ\text{C}$  and has a

temperature coefficient of 1.9 mV/ $^\circ\text{C}$ .

The micropower, single-supply op amp IC<sub>2</sub> buffers the current drain on  $V_{\text{TEMP}}$ , which can supply no more than 50 nA. The second op amp (IC<sub>3</sub>) regulates  $I_{\text{OUT}}$  as illustrated by the equation for current summation at the op amp's noninverting input:

$$I_{\text{OUT}} = \frac{V_{\text{TEMP}}(R_6 + R_7)}{R_2 R_8} - \frac{V_{\text{SET}}(R_2 + R_6 + R_7)}{R_2 R_8}$$

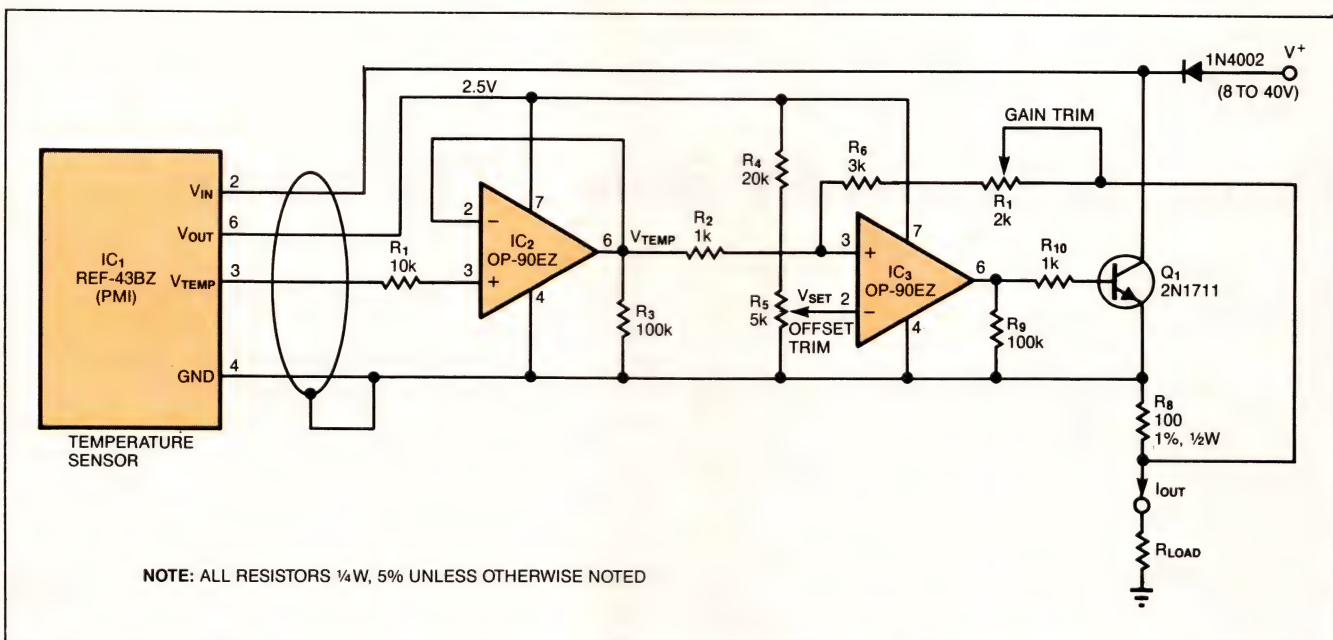


Fig 1—This circuit generates a 4- to 20-mA current output that is proportional to temperature. Gain and offset trims do not interact.



# DESIGN IDEAS

You obtain the variation of  $I_{OUT}$  with temperature by differentiating the transfer function:

$$\frac{\Delta I_{OUT}}{\Delta T} = \frac{\frac{\Delta V_{TEMP}}{\Delta T} (R_6 + R_7)}{R_2 R_8}$$

The formulas show that the gain and offset trims do not interact if you trim the gain first. To trim the gain, first place the sensor ( $IC_1$ ) in an ice-water bath ( $0^\circ\text{C}$ ) and, if necessary, adjust the offset-trim potentiometer ( $R_5$ ) so that  $I_{OUT}$  is greater than 4 mA. Record  $I_{OUT}$ . Next, place the sensor in boiling water ( $100^\circ\text{C}$ ). Adjust the gain-trim resistance ( $R_6 + R_7$ ) so that  $I_{OUT}$  produces the desired mA/ $^\circ\text{C}$  ratio:

$$\text{OUTPUT RATIO} = \frac{\Delta I_{OUT}}{\Delta T_{OPERATING}} = \frac{16 \text{ mA}}{\Delta T_{OPERATING}}$$

If the transmitter is to operate over  $-50$  to  $150^\circ\text{C}$ , for example, then

$$\begin{aligned} \text{OUTPUT RATIO} &= \frac{16 \text{ mA}}{150^\circ\text{C} - (-50^\circ\text{C})} \\ &= \frac{16 \text{ mA}}{200^\circ\text{C}} = 0.08 \text{ mA}/^\circ\text{C} \end{aligned}$$

Suppose the  $I_{OUT}$  value that corresponds to  $0^\circ\text{C}$  is 6.3 mA. Then at  $100^\circ\text{C}$ ,

$$\begin{aligned} I_{OUT(100^\circ\text{C})} &= I_{OUT(0^\circ\text{C})} + 100^\circ\text{C} (0.08 \text{ mA}/^\circ\text{C}) \\ &= 6.3 \text{ mA} + 8 \text{ mA} = 14.3 \text{ mA} \end{aligned}$$

TABLE 1—GAIN-TRIM VALUES

TEMPERATURE RANGE	$R_6$ (FIXED)	$R_7$ (VARIABLE)
$0^\circ\text{C}$ TO $70^\circ\text{C}$	10 k $\Omega$	5 k $\Omega$
$-15^\circ\text{C}$ TO $85^\circ\text{C}$	6 k $\Omega$	3 k $\Omega$
$-50^\circ\text{C}$ TO $150^\circ\text{C}$	3 k $\Omega$	2 k $\Omega$

Therefore, you should adjust  $R_6$  so that  $I_{OUT} = 14.3$  mA while the sensor is at  $100^\circ\text{C}$ .

Finally, you can adjust the offset at any temperature  $T_{AMBIENT}$  without affecting the gain trim:

$$I_{OUT} = \frac{16 \text{ mA} (T_{AMBIENT} - T_{MIN})}{\Delta T_{OPERATING}} + 4 \text{ mA}$$

At  $20^\circ\text{C}$  in the above example,

$$\begin{aligned} I_{OUT} &= \frac{16 \text{ mA}}{200^\circ\text{C}} (20^\circ\text{C} - (-50^\circ\text{C})) + 4 \text{ mA} \\ &= 9.6 \text{ mA} \end{aligned}$$

Table 1 shows the  $R_6$  and  $R_7$  values required for various temperature ranges. **EDN**

To Vote For This Design, Circle No 748

## Derive $\pm 15\text{V}$ and $5\text{V}$ from a $12\text{V}$ battery

Andy Jenkins  
Maxim Integrated Products, Sunnyvale, CA

Parts for the triple-output dc/dc converter shown in Fig 1 cost about \$11 in 100-piece quantities. The circuit converts the  $12\text{V}$  output of a lead-acid battery to isolated  $\pm 15\text{V}$  supply voltages plus a nonisolated  $5\text{V}$  supply voltage.

$IC_1$  is a switching-regulator chip normally used in step-up applications, but the transformer and circuit shown allow the device to provide a step-down function as well. The chip generates a  $45\text{-kHz}$  signal that drives the gate of MOSFET  $Q_1$ .

$Q_1$  turns on when the gate voltage is high, causing a linear increase in  $T_1$ 's primary current, which stores energy in a magnetic field. The field starts to collapse as  $Q_1$  turns off, reversing the voltage polarity on all windings and causing the voltage on each secondary winding to increase. These secondary voltages then deliver energy to the outputs by forward-biasing the Schottky diodes  $D_1$ ,  $D_2$ , and  $D_3$ . When the  $5\text{V}$  output rises above a desired level, feedback to the chip causes an internal error comparator to turn off the gate signal to  $Q_1$ .

The secondary-winding ratios set the output-voltage levels, and close coupling between the trifilar windings



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# DESIGN IDEAS

assures good load regulation for the  $\pm 15\text{V}$  supplies (regulation is about 2% for a 10 to 100% load change). For better regulation, you can set the output voltage higher and add linear regulators. The inductors  $L_1$  and  $L_2$  block high-frequency ringing from the transformer that would otherwise boost the  $\pm 15\text{V}$  outputs out of spec when lightly loaded. For best regulation, you should provide minimum loads of 10% for the 15V supplies and 20% for the 5V supply.

The circuit can accommodate the 8 to 16V range associated with the terminals of a lead-acid battery. What's more, the protection network made up of resistor  $R_1$  and zener diode  $D_4$  allows the circuit to withstand 50V for 1 msec—a classic overvoltage test that simulates the load dump of an automobile's alternator when you turn off the ignition. For an input change of 8 to 16V, the 5V output's line regulation is typically 0.2%.

Battery current is about 600 mA for nominal operation, but current peaks in the primary winding can be 4A or more. Therefore, you should provide good-quality ground connections and short, low-impedance connec-

tions to the transformer and the MOSFET. Close decoupling using ceramic and electrolytic capacitors also reduces output noise. With proper circuit layout, the output noise is about 50 mV at the 5V output and 30 mV at the 15V outputs.

The transformer, constructed with a ferrite pot core that offers low loss and minimal magnetic leakage, has a primary inductance of about  $21\text{ }\mu\text{H}$  for the power levels shown. You must choose a core size and material that will handle the 4A peak currents without saturation. The 15V secondaries have 2.9:1 turns ratios, which provide the desired 3:1 voltage ratio after covering the rectifier losses. Actual turns are as follows: the primary,  $11\frac{1}{2}$  turns; the 15V secondaries,  $11\frac{1}{2}$  turns each; the 5V secondary, four turns. High circuit efficiency (about 75% at full load with a 12V input) eliminates any need for a heat sink on the MOSFET.

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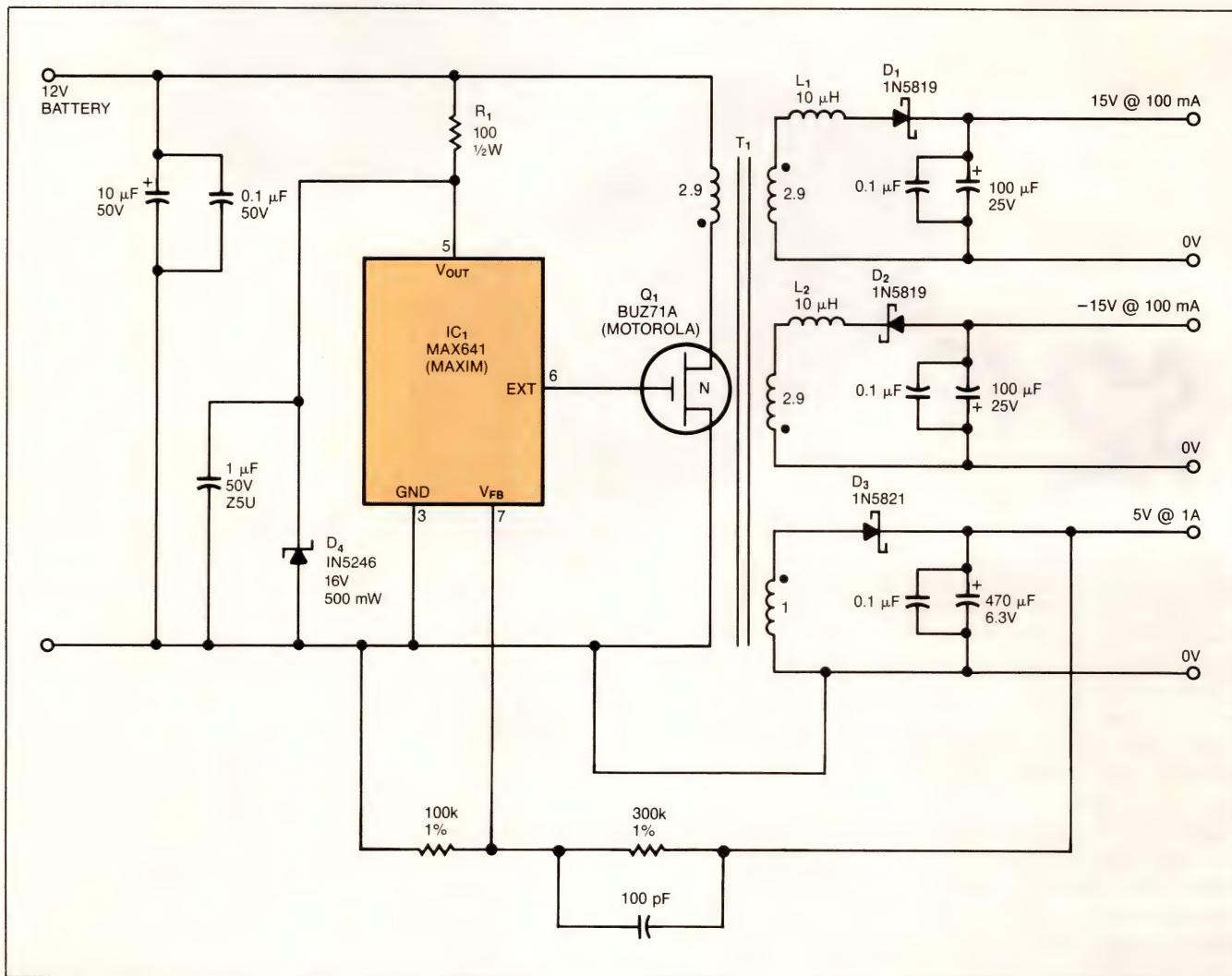
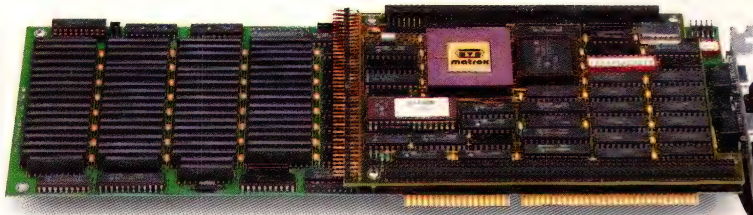


Fig 1—This triple-output dc/dc converter requires only one IC.



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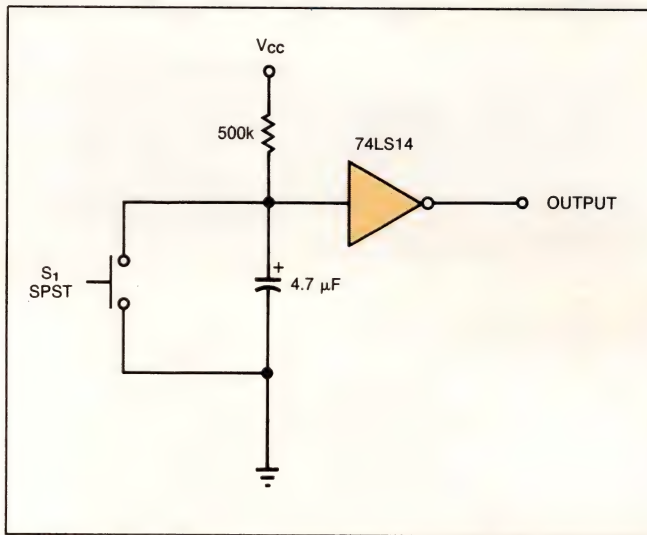
The winning Design Idea for the November 12, 1987, issue is entitled "Step-up converter produces 5V from 1.5V," submitted by Gerald Grady of Maxim Integrated Products (Sunnyvale, CA).

## Switch debouncer uses few parts

Bill McClelland

Stahl Research, Port Chester, NY

When debouncing is important, designers often use an spdt switch for an spst function (*EDN*, October 29, 1987, pg 252). You can debounce an spst switch, however, using a single Schmitt-trigger inverter (**Fig 1**).



**Fig 1**—This simple spst switch debouncer relies on the inverter's internal pullup resistor. An external resistor allows use of a CMOS gate.

The TTL inverter (74LS14) has an internal 16-k $\Omega$  pullup resistor that pulls the gate input high when the switch is open. As you close the switch, the 4.7- $\mu$ F capacitor discharges on the first contact; if the switch contacts bounce open, the internal resistor limits the capacitor's recharge to a rate sufficiently slow to prevent an undesired gate transition before the contacts again close. Note that the circuit correctly debounces the switch for both opening and closing. If you add an external pullup resistor (dotted lines), you can use a CMOS Schmitt-trigger gate (74HC14) and a smaller (0.1  $\mu$ F) capacitor.

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We offer six 3½" drives with 21, 32 and 48 MB formatted capacities. You also have a choice of interfaces: SCSI or ST412 with RLL or MFM encoding. All with 28 msec access time.

Our 3½" drives use Seagate's field-proven, proprietary stepper motors to achieve fast access times normally found only with more expensive voice coil actuators.


Seagate's 3½" drives are not only fast—they're power savers, using as little as 8 watts. And for added data integrity, the drives feature autopark with a balanced positioner.

All of Seagate's 3½" drives are built with the precision and quality that have made us the world's leading independent manufacturer of 5¼" full-height and half-height hard disc drives.

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When you're ready to go for a little drive, give us a call. 800-468-DISC.

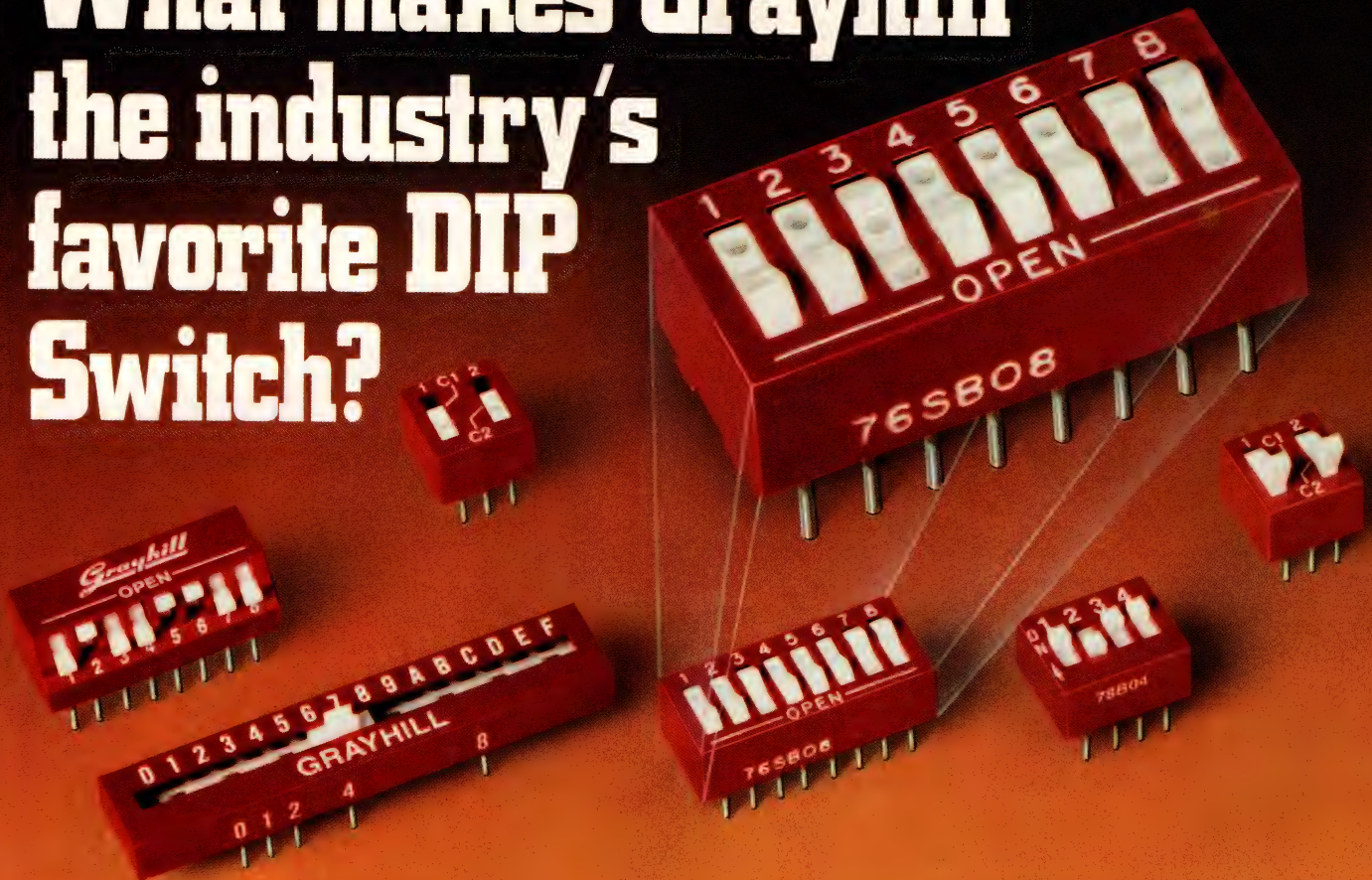


 **Seagate**

The first name in disc drives.

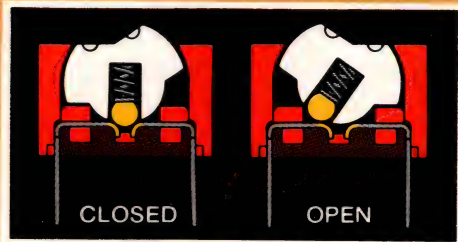


# What makes Grayhill the industry's favorite DIP Switch?



## The Difference in Performance...

Grayhill DIP switches are the popularity leaders, and the number one reason is their reliable long-term operation. Talk about performance! Our exclusive spring-loaded ball contact system provides up to 10,000 cycles at logic loads, plus these additional performance benefits: high contact pressure for sure, solid switching; positive wiping action to assure clean contacts throughout the switch life; and immunity to shock and vibration.



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**Actuation choice:** rockers or slide (raised or recessed), toggles, or side actuated.

**Number of positions:** 2 to 12.

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Top performance in the field goes hand-in-hand with ease of handling in your plant:

- Bases are epoxy-sealed; optional top seal provides further protection during cleaning
- Our QC reduces yours—we do 100% electrical inspection, 100% pin straightening
- Machine insertable switches available

## The Difference in Procurement...

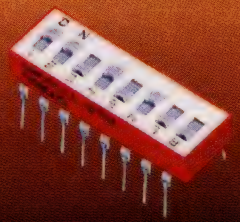
Grayhill DIP switches are not only competitively priced, but features that are extras elsewhere are standard at Grayhill. For even greater purchasing convenience, most types are available off-the-shelf. Choose your preferred source—you can order direct from Grayhill or from your local authorized distributor.

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### Machine Insertable DIP Switch

- Compatible with leading TO-116 IC insertion equipment
- Cartridge packed for easy loading
- 4 through 10 station switches



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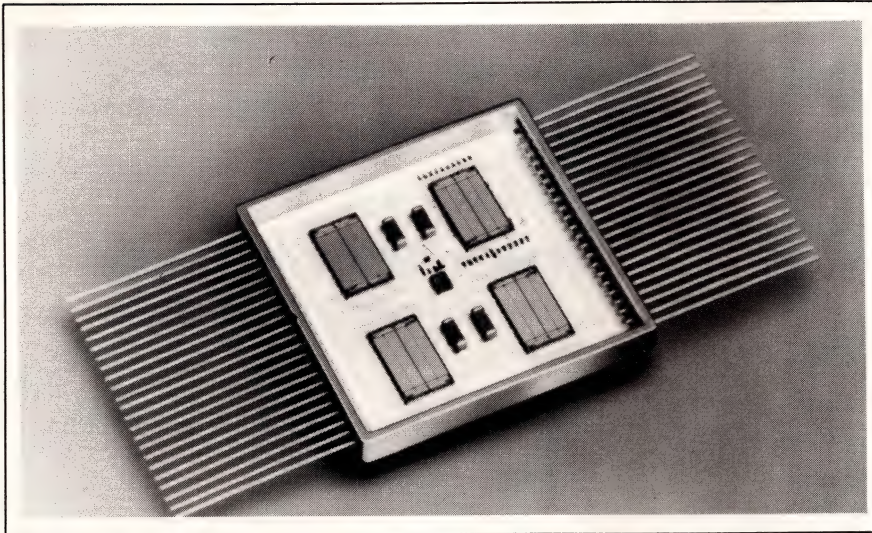
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# NEW PRODUCTS

## INTEGRATED CIRCUITS



### STATIC-RAM IC

- Provides 1M-bit memory
- Screened to MIL-STD-883

The MEM-84000 hybrid IC comes in a  $1.25 \times 1.25 \times 0.15$ -in. hermetic flatpack and uses four TTL-compatible  $32k \times 8$ -bit RAM chips to implement its 1M-bit memory. The unit's 100-nsec access time,  $64k \times 16$ -bit memory organization, and  $-55$  to  $+125^\circ\text{C}$  operating temperature range suit it for use with 16- or 32-bit CPUs in military processor applications. Data transfers to the device are made using 16 address

lines, 16 data lines, and standard read, write, and enable lines. You can use external decoding to expand the unit's memory to any width or depth. The unit operates from a 5V supply. Its low-power CMOS construction allows battery backup, which prevents data loss in the event of power failure. The unit retains data even when operating on battery voltages as low as 2V. \$750. Delivery, stock to 90 days ARO.

**ILC Data Device Corp.**, 105 Wilbur Pl, Bohemia, NY 11716. Phone (516) 567-5600. TWX 310-685-2203.

Circle No 385

### MICROCONTROLLER

- Has three more ports than the 87C51 microcontroller
- Features 56 I/O pins

The 7-port EPROM-based SC87C451 microcontroller has all the features of the industry-standard 87C51 and three more 8-bit, bidirectional ports. The three ports provide 24 additional I/O pins, which you can use in telemetry, printer, process-control, and disk-drive applications; you can also use the unit to advantage in distributed-processing applications. You can program one of the three ports for

3-state control. Using four handshaking pins, you can load the unit via a  $\mu\text{P}$  system as you would a RAM. The microcontroller stores its control program in 4k bytes of EPROM; you can quickly test various prototype control programs by erasing the control program in the EPROM through the microcontroller's quartz window and loading a new control program. In a 68-pin PLCC, \$95; in a 64-pin ceramic DIP, \$85 (100).

**Signetics Corp.**, 811 E Arques Ave, Sunnyvale, CA 94088. Phone (408) 991-2000.

Circle No 386

### VIDEO MULTIPLEXER

- Features eight channels
- Has 300-MHz bandwidth

The DG538 8-channel video multiplexer has low drive requirements and provides TTL compatibility, address-latch data readback, a 300-MHz bandwidth, and  $-97$ -dB crosstalk at 5 MHz. The unit's analog signal range allows  $\pm 5\text{V}$  signal swings, eliminating the need for a bias circuit and coupling capacitors at the multiplexer's input and output. All of the monolithic IC's signal lines are fully isolated from adjacent signal lines, and the unit features  $55\Omega$  on-resistance and 8-pF max drain capacitance. Applications for the unit include high-quality video systems, wideband information-distribution systems, cable and studio TV equipment, and medical imaging systems. In a 28-pin DIP, \$11.52; in a PLCC, \$13.01 (100).

**Siliconix Inc.**, 2201 Laurelwood Rd, Santa Clara, CA 95054. Phone (408) 988-8000.

Circle No 387

### A/D CONVERTER

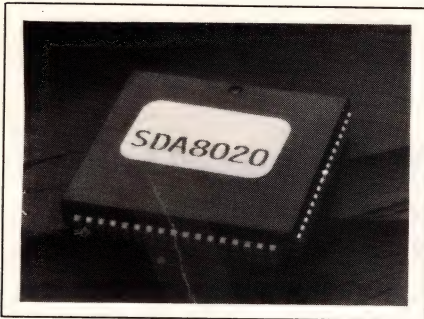
- Offers 10-bit resolution
- Provides 20M-samples/sec

According to the manufacturer, the TDC1020 is the first monolithic flash A/D converter to offer 10-bit resolution at a guaranteed 20M-sample/sec rate. Its target applications include radar and studio-quality video systems. The device is also suitable for use in medical-imaging applications and for high-speed data conversion. The converter operates over the commercial temperature range and comes in a 64-pin DIP. \$295 (1000).

**TRW LSI Products**, Box 2472, La Jolla, CA 92038. Phone (619) 457-1000.

Circle No 388





## SHIFT REGISTER

- *Multiplexes and demultiplexes 8-bit data streams*
- *Offers ECL-compatible inputs*

The SDA-8020 is a 4/8-bit shift register for use as an interface between high-speed A/D or D/A converters and the memories in a data-acquisition system. Featuring ECL-compatible signal inputs, the device can demultiplex an 8-bit data stream having a clock speed as high as 100 kHz into four parallel 8-bit TTL data channels having a clock speed 25% less than that of the serial

clock. Conversely, a multiplexing mode can reverse this action. The cascable shift register has two clock outputs, and all its external control signals are TTL compatible. It provides special signals to drive high-speed CMOS static RAMs. The chip is packaged in a 68-pin PLCC and consumes 1.5W. \$70 (100).

**Siemens Corp.**, 2191 Laurelwood Rd, Santa Clara, CA 95054. Phone (408) 980-4577.

Circle No 389

## DTMF RECEIVER

- *Detects all 16 DTMF tone pairs*
- *Combination decoder and filter*

The G8870 receiver on a chip is a combination Touch-Tone decoder and filter. It detects all 16 DTMF tone pairs and converts them to code. It can also distinguish sound frequencies that approximate DTMF signals from actual DTMF

signals, selectively passing only the latter to the output bus. The device consumes 35 mW max. It comes in an 18-pin DIP or a 20-pin plastic leaded chip carrier. \$5.25 (100).

**California Micro Devices Corp.**, Microcircuits Div, 2000 W 14th St, Tempe, AZ 85281. Phone (602) 921-4540.

Circle No 390

## CMOS COMPARATORS

- *Low current consumption*
- *Duals and quads available*

Fabricated in LinCMOS, the TLC393 (dual) and TLC339 (quad) micropower comparators consume only 5% of the current normally required by their pin-compatible bipolar counterparts, the LM393 and LM339. When the micropower comparators are operating from a 5V supply, the typical power dissipation of each independent compara-

# Color by

**Q**uadram's new Quad HPG™ graphics adapter delivers unbeatable PC graphic capabilities. Brooktree makes it possible with an unbeatable triple 8-bit RAMDAC that provides 256 colors from a 16 million palette.



## MICROPOWER LinCMOS™ COMPARATORS

**LM339/393 PERFORMANCE  
1/20 THE CURRENT**



tor in the micropower chips is only 50  $\mu$ W; the response time is typically 2.5  $\mu$ sec at 5 mV of overdrive. The TLC393 and TLC339, like the LM393 dual and LM339 quad, have open-drain outputs that can interface to a variety of loads and supplies and to logic functions. In contrast to the 393 and 339 types, two other LinCMOS types, the TLC3702 dual and the TLC3704 quad have push-pull outputs that eliminate the need for external pullup resistors for driving capacitive loads. All four micropower LinCMOS comparators operate from single-supply voltages of 3 to 16V for versions in the commercial and industrial temperature

ranges or 4 to 16V for versions in the military temperature range. A variety of DIP and SO packages are available. Plastic-DIP commercial devices, from \$0.52 to \$0.73 (100).

**Texas Instruments Inc.**, Semiconductor Group (SC-764), Box 809066, Dallas, TX 75380. Phone (800) 232-3200, ext 700.

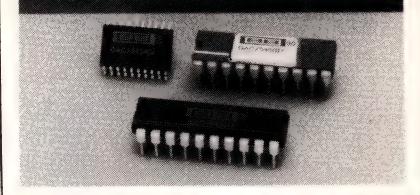
**Circle No 391**

## CMOS 12-BIT DAC

- *Performs 4-quadrant multiplication*
- *Features TTL/CMOS-logic compatibility*

The DAC7545 buffered, 12-bit multiplying D/A converter is a pin-compatible replacement for industry standards such as the AD7545 and PMI7545. The device features 12-bit  $\mu$ P-interface logic and loads data as 12-bit data words. It processes data when the Chip Select and Write

## 12-Bit Buffered CMOS DACs



pins are both at logic lows. Because it is a multiplying DAC, it supplies output that is the product of the digital input code and an external analog reference signal. The DAC's reference input can vary between  $\pm 20$ V; with the addition of external op amps at its output, the device can perform 4-quadrant multiplication. The converter features 10-nA max output leakage and 70-pF max output capacitance. In a plastic DIP, \$8; in a small outline package, \$9.20; in a ceramic DIP, \$9.50 (100).

**Burr-Brown**, Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. TLX 666491.

**Circle No 392**  
*Continued on pg 253*

# Brooktree®



**Brooktree Bt453.** Triple 8-bit 40 MHz RAMDAC with 256 color lookup table. Monolithic CMOS.

**Quadram Quad HPG.** 640 x 480 x 8 high performance graphics adapter board for IBM PC family, IBM Personal System/2™ Model 30, and compatibles.

Brooktree Corporation, 9950 Barnes Canyon Road, San Diego, California 92121. 1-800-VIDEO IC or 1-800-422-9040, in California.

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**CIRCLE NO 27**



# 33kHz 12-BIT DSP A/D's

**MIL-STD-1772  
CERTIFIED**

MN6227/MN6228

12-Bit Sampling A/D's

Sampling Rate: 33kHz Minimum

Input Bandwidth: 16.5kHz Minimum

Testing: Frequency Domain (FFT)

Signal-to-Noise Ratio: 70dB Minimum

Harmonics: -80dB Minimum

Price: \$74/100's



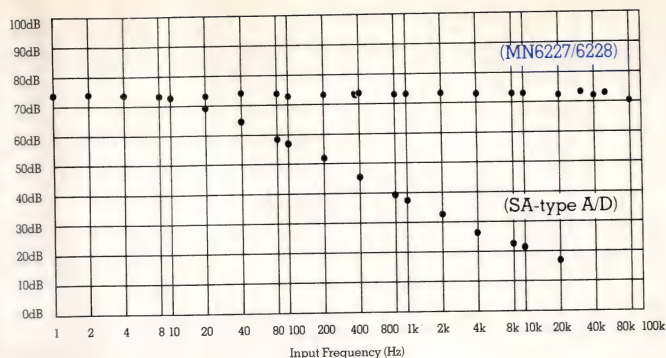
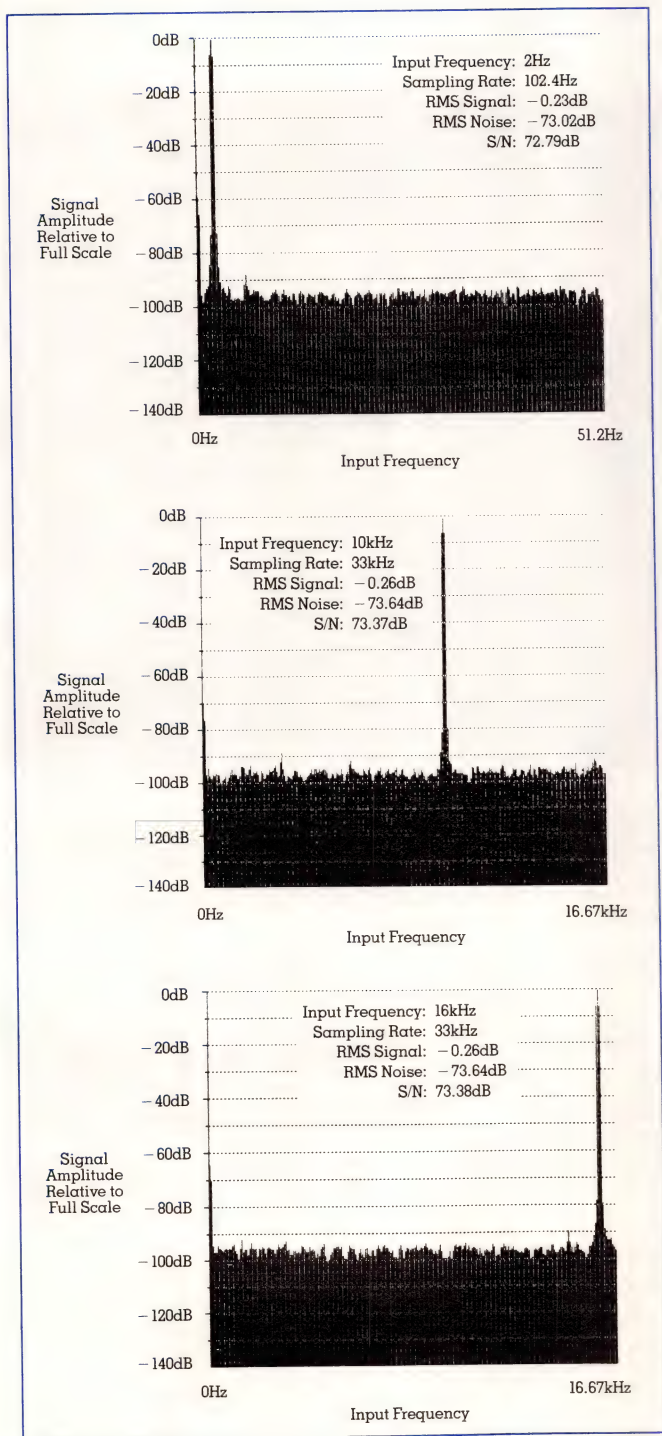
You are looking at the *first* commercially-available, *FFT-tested*, high-speed, 12-bit, sampling A/D converters *specified* for digital-signal-processing applications. MN6227 and MN6228 are 33kHz A/D's with internal track-and-hold amplifiers. They are ideally suited for radar, sonar, spectrum and vibration analysis, voice and signature recognition, and other contemporary DSP applications. Unlike traditional successive-approximation A/D's without track-hold amplifiers,

these true sampling A/D's maintain near-ideal signal-to-noise ratios independent of increasing analog input frequencies. They are *made* for the frequency domain.

Note the FFT spectra (right) and the data plot (top right). They clearly demonstrate the ability of these devices to maintain SNR with increasing input frequencies. In our frequency-domain testing, these devices operate in a manner that simulates a



digital spectrum analyzer with a known low-distortion input signal. The output spectra yield precise, practical measurements of signal level, noise level, signal-to-noise ratio, harmonic distortion, and input bandwidth... the keys to specifying for DSP applications.

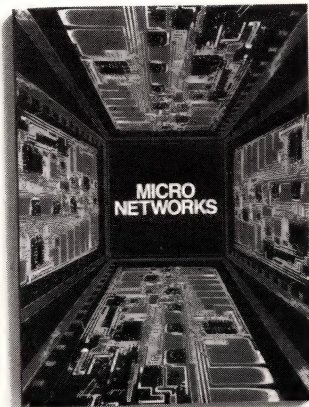


This plot of actual recorded data demonstrates MN6227/6228's ability to maintain near-ideal SNR with increasing input-signal frequency, while A/D's without companion track-holds show rapid (6dB/octave) SNR degradation.

MN6227/6228 are the first A/D's in our new MN6000 series. The 12 and 16-bit converters in this series all contain internal, user-transparent, track-hold amplifiers that enable each device to accurately sample and digitize dynamically changing input signals with frequency components up to the Nyquist frequency (one-half the sampling rate).

MN6227/6228 have a full 8 or 16-bit  $\mu$ P interface and are packaged in small, low-profile, 28-pin ceramic DIP's, with the industry-standard MN574A pinout.

For detailed information on MN6227/6228, send for our comprehensive data sheet. For rapid response and a copy of our 384-page catalog of data conversion products, call Russ Mullett at (617) 852-5400, x 208.



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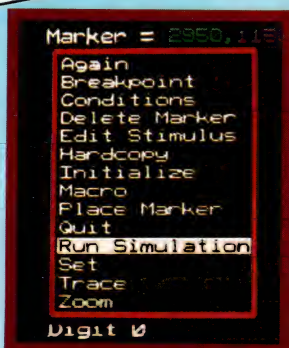
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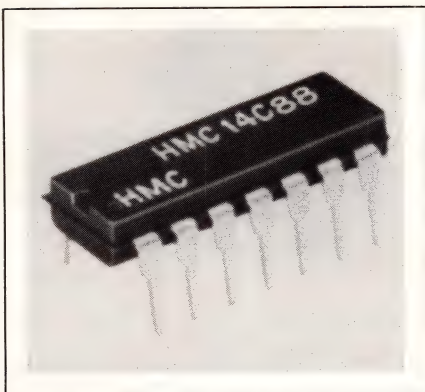
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## INTEGRATED CIRCUITS



### QUAD LINE DRIVER

- CMOS device operates from supply voltages of 4.5 to 15V
- Conforms to RS-232C and CCITT V.24/V.28 specifications

The CMOS HMC14C88 is a replacement for the TTL 1488 bipolar quad line driver. The inputs are compatible with both TTL and CMOS levels and are nominally centered to switch at 1.4V. The outputs switch to within 75% of the supply rails while driving RS-232C line loads of 3 to 7 k $\Omega$ . The outputs are also short-circuit protected, provide a minimum power-down output impedance of 300 $\Omega$ , and have a propagation delay of less than 2  $\mu$ sec. \$0.72 (1000).

HMC, 1235 Walt Whitman Rd, Melville, NY 11747. Phone (516) 673-6505.

Circle No 393

### QUAD POWER DRIVER

- Output current to 2.5A
- Output voltages to 60V

The SG3645 quad driver for stepper motors comes in a 16-pin Batwing package. Each of its four open-collector Darlington outputs has a breakdown voltage rating of 60V and a current rating of 2.5A. A common enable signal can enable or disable all four outputs simultaneously. Each of the device's four channels have TTL-compatible inputs and integral transient-suppression diodes in the outputs. The circuit has a thermal shutdown

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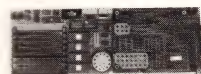
### CAT902

10 MHz, 1 wait: Up to 1 meg RAM. 128K PROM: Dual floppy controller: SCSI hard disk interface: 1 parallel and 2 serial ports: EGA and 80287 optional: Keyboard port, speaker, reset / key lock / turbo ports



### CAT910

CAT900 Features plus: EGA extended resolution (1280 x 800): CGA and monochrome modes: 1280 x 800, 640 x 480, 640 x 350, and 640 x 200 resolutions



### CAT911

CAT 901 Features plus: EGA extended resolution (1280 x 800): CGA and monochrome modes: 1280 x 800, 640 x 480, 640 x 350, 640 x 200 resolutions



### CAT901

12 MHz, 0 wait: Dynamic clock speed change: Up to 4 meg RAM. 64K PROM: PROM set-up routines: Dual floppy controller: ST506 hard disk interface: 1 parallel and 2 serial ports: EGA and 80287 optional: Keyboard port, speaker, reset / keylock / turbo ports

### CAT900

12 MHz, 0 wait: Up to 8 meg RAM. 64K PROM: 1 parallel and 2 serial ports: EGA and 80287 optional: Keyboard port, speaker, reset, keylock, turbo port

### CAT912

CAT902 features plus: EGA extended resolution (1280 x 800): CGA and monochrome modes: 1280 x 800, 640 x 480, 640 x 350, and 640 x 200 resolutions

### QUANTITY CUSTOM DERIVATIVES AVAILABLE

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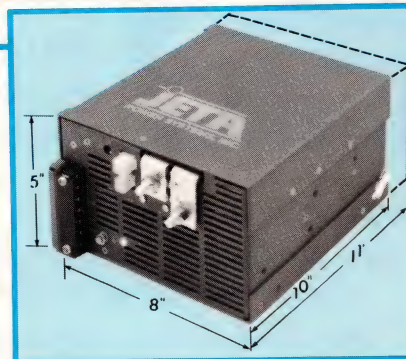
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**See EEM pages D1706-1708**



**POWER SYSTEMS, INC.**

2675 Junipero Avenue ■ Signal Hill, CA 90806  
Tel: 213/427-0095 ■ TWX: 510-101-1804 ■ FAX: 2134262417

CIRCLE NO 29



feature. The SG3645 is specified for operation at junction temperatures from 0 to 125°C. Samples are available from stock. \$2.65 (100). Delivery, 60 days ARO.

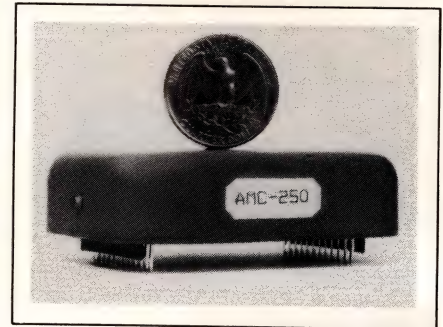
**Silicon General**, 11861 Western Ave, Garden Grove, CA 92641. Phone (714) 898-8121. TWX 910-596-1804.

Circle No 394

## SERVO AMPLIFIER

- 250W capability
- 30-kHz PWM frequency

The AMC-250 contains a complete dc velocity servo amplifier that provides protection against output short circuits, overheating, and overvoltage. The device also has a compensation adjustment to opti-



mize response, and an adjustable current limit. The device doesn't require an external heat sink or forced-air cooling for most duty cycles, even at its maximum output of  $\pm 50V$  at  $\pm 5A$ . The device operates at any supply voltage from 20 to 50V and measures  $1.62 \times 2.75 \times 0.75$  in. \$149.

**Advanced Motion Controls**, 15921 Haynes St, Van Nuys, CA 91406. Phone (818) 989-4480.

Circle No 395



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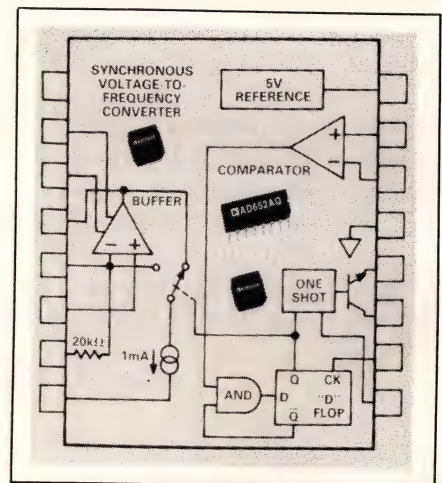
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## V/F CONVERTER

- Full-scale frequency of 2 MHz
- Maximum nonlinearity of  $\pm 0.005\%$

The AD652 can perform a V/F conversion to 14-bit accuracy (16-bit resolution) in 32.77 msec at 2 MHz. The internal 5V reference can supply 10 mA to an external load. You can apply an external clock to the device, in synchronous mode, to set its full-scale frequency. The AD652 is pin compatible with the AD651 and VFC100 synchronous V/F converters. The device operates from a

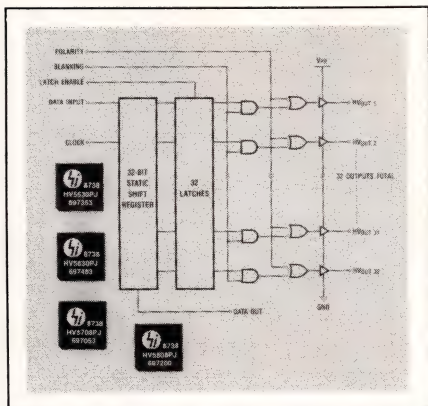


## INTEGRATED CIRCUITS

12 to 18V supply for unipolar operation or from a  $\pm 6$  to  $\pm 18$ V supply for bipolar applications. The packaging options include a 20-terminal PLCC or a 16-pin ceramic DIP. The device is available in three temperature ranges and two accuracy grades. \$6.95 to \$13.65 (100).

Analog Devices, Literature Ctr, 70 Shawmut Rd, Canton, MA 02021. Phone (617) 935-5565. TWX 710-394-6577.

Circle No 396



### DRIVERS

- Provide 32 channels
- Feature 80 and 300V ratings

The HV55 and HV56 300V drivers and the HV57 and HV58 80V drivers combine high-speed, low-power CMOS logic with high-voltage DMOS outputs. The HV55 and its reverse-shift complement, the HV56, have 32 open-drain, 300V N-channel outputs, each of which can sink 100 mA. A built-in, 8-MHz shift register controls the outputs and offers polarity and blanking control. The combination of the two control features provides flexibility for driving flat-panel displays. The HV57 and its reverse-shift complement, the HV58, have 32 push-pull, 80V outputs, each of which can source or sink 20 mA. You can use these units to drive nonimpact printers and electroluminescent, plasma, and liquid-crystal displays. The devices come in 44-pin PLCC J-lead packages. From \$6.34 (1000).

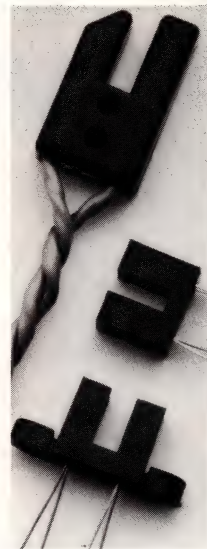
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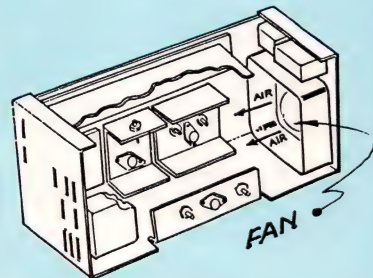
**HEI inc.**

Optoelectronics Division

P.O. Box 5000 1495 Steiger Lake Lane  
Victoria, MN 55386

CIRCLE NO 30

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For cooler operating high-current single and multiple output power supplies from 500 to 2200 watts, contact JETA.

**See EEM pages D1706-1708**



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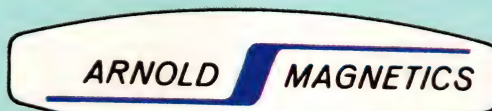
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CIRCLE NO 214

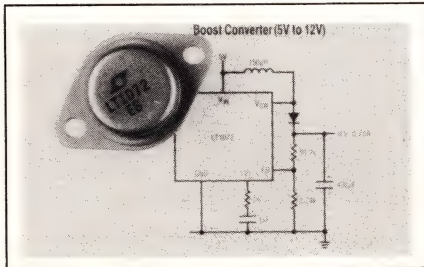


## INTEGRATED CIRCUITS

Delivery, six to eight weeks ARO.

**Supertex Inc.**, 1225 Bordeaux Dr,  
Box 3607, Sunnyvale, CA 94088.  
Phone (408) 744-0100. TWX 310-  
683-9143.

Circle No 397



### SMPS REGULATOR

- Features on-chip 1.25A switch
- Operates from 3 to 60V

The LT1072 regulator IC includes an on-chip 1.25A output switch and comes in either a 5-pin TO-3 or TO-220 package. The SMPS (switch-mode power supply) unit operates over a 3-to-60V input voltage range, and you can synchronize it with a system clock that operates from 48 to 70 kHz. The regulator uses an adaptive antisaturation switch drive that permits a wide range of load currents at low-saturation voltage and high operating efficiency. The IC operates in all standard switching configurations, including the buck, boost, flyback, and forward configurations. Designers with little experience in switch-regulator applications will find the chip easy to use: It features a built-in oscillator; integral control and protection circuitry; and built-in circuitry for producing a fully isolated flyback regulator, thus eliminating the need for optocouplers or extra transformer windings. A shutdown mode, which you activate externally, reduces total standby-operation current to 50  $\mu$ A typ. In a TO-220 package, \$4.25 (100).

**Linear Technology Corp.**, 1630  
McCarthy Blvd, Milpitas, CA 95035.  
Phone (800) 637-5545; in CA, (408)  
432-1900.

Circle No 398

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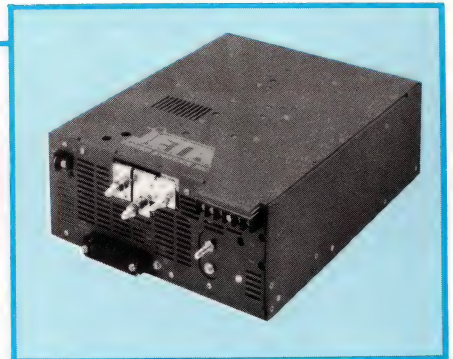
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WATTS**



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High reliability is derived from a reduced component count, high-voltage transistor V-I load reshaping for maximum SOA and careful thermal management to ensure the best operating environment for critical components.

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See EEM pages D1706-1708

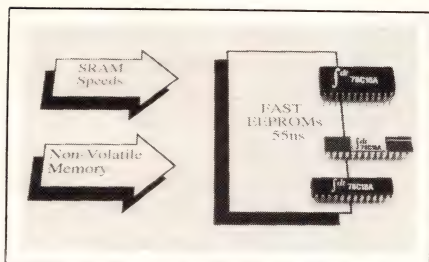


**POWER SYSTEMS, INC.**

2675 Junipero Avenue ■ Signal Hill, CA 90806

Tel: 213/427-0095 ■ TWX: 510-101-1804 ■ FAX: 213/4262417





## CMOS EEPROMs

- 55-nsec read access time
- Serial programming I/O channel

The IDT78C16 is a 16k-bit EEPROM featuring a 55-nsec access time; it's pin compatible with slower (150-nsec) types. Along with the 55-nsec access time, the IDT78C18 features a serial-I/O channel that allows rewrites independently of the target system's  $\mu$ P. Additionally, you can write to both devices in the customary, parallel manner. Both devices have onboard charge pumps for generating programming super-voltages from a single 5V supply. The IDT78C16 and IDT78C18 are

available in a variety of ceramic DIP and LCC packages. From \$15 (100).

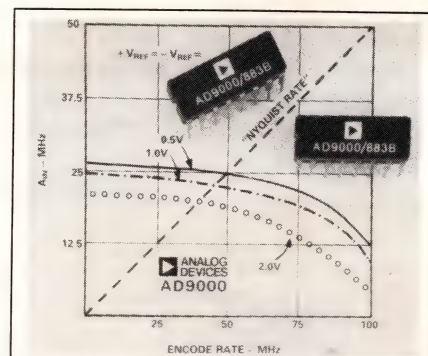
**Integrated Device Technology Inc.**, Box 58015, Santa Clara, CA 95052. Phone (408) 727-6116. TWX 910-338-2070.

Circle No 399

## 6-BIT ADC

- Features 75M-sample/sec encode rate with no missing codes
- Processed to MIL-STD-883B rev C

The AD9000 flash A/D converter guarantees a minimum encode rate of 75M sample/sec. You can use it in telecommunications, electronic-warfare-systems, and radar-guidance applications. The device features dc specifications of  $\pm 1$ -LSB max differential and integral nonlinearity, and  $\pm 1.5$ -LSB max initial offset error. Its dynamic linearity specs at  $\pm 0.5$  LSB typ, when measured with a 15-MHz input signal. It

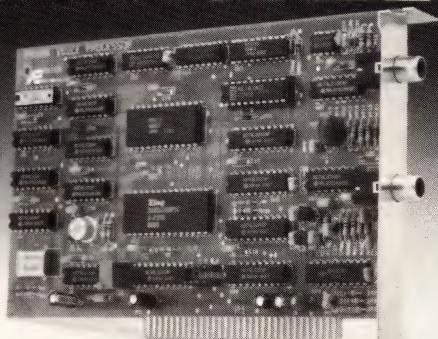


features a 42-dB signal-to-noise ratio, 44-dB in-band harmonics, and 46-dB 2-tone intermodulation rejection. An overflow bit lets you cascade converters to achieve higher resolution without reducing the sampling rate. AD9000SD/883B rev C, in a 16-pin DIP, \$110; AD9000SE/883B rev C, in a 28-pin LCC, \$120 (100).

**Analog Devices**, Literature Center, 70 Shawmut Rd, Canton, MA 02021. Phone (617) 935-5565. TWX 710-394-6577.

Circle No 400

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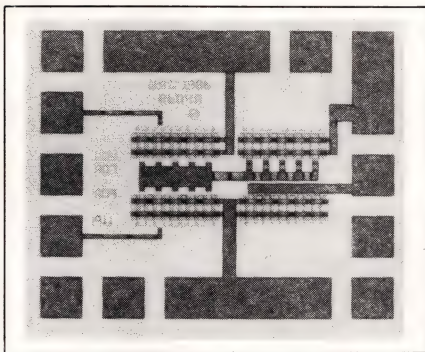
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## INTEGRATED CIRCUITS



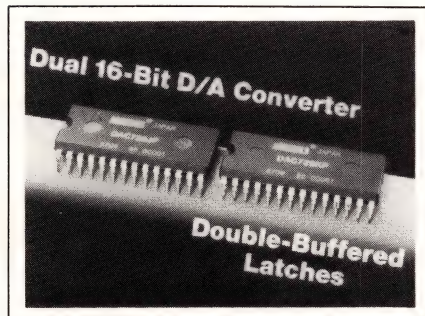
### LASER-DIODE DRIVER

- GaAs laser-diode current modulator
- Minimum bandwidth of 1.5 GHz

The LDCM 1500A is a monolithic laser (or LED) driver for use in analog or digital fiber-optic systems. The device offers a minimum bandwidth of 1.5 GHz and a frequency response as high as 2.5 GHz. You can configure the input as either single-ended or differential. The bias current and the modulation current are both rated at 70 mA, and both are adjustable. The LDCM 1501A comes in a 10-pin surface-mount package. LDCM 1500A chip, \$33 (100). Delivery for prototypes, four to eight weeks ARO.

**Microwave Semiconductor Corp.**, 100 School House Rd, Somerset, NJ 08873. Phone (201) 563-6530.

Circle No 401



### DUAL 16-BIT DAC

- Double-buffered input register
- 14-bit monotonicity

The DAC725 is a dual, 16-bit DAC that incorporates dual, double-buffered data latches, a precision internal buried-zener voltage reference,

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CIRCLE NO 35

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See EEM pages D1706-1708



**POWER SYSTEMS, INC.**

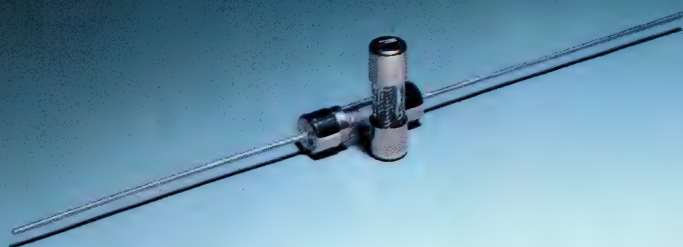
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## INTEGRATED CIRCUITS

and output op amps. The device provides 16-bit resolution and 14-bit monotonicity over temperature. The output range is  $\pm 10V$ , and the settling time for a full-scale step is 4  $\mu\text{sec}$ . Integral linearity error is  $\pm 0.003\%$  of full scale. The design employs two DACs and two CMOS gate-array latch chips. The device loads data in two 8-bit bytes and provides separate lines for functions such as chip select, latch control, and clear. The device comes in a 28-pin plastic DIP. \$34.90 (100).

**Burr-Brown Corp.**, Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. TLX 666491.

Circle No 402

## DUAL-POWER OP AMPS

- *Deliver output currents as high as 2.5A*
- *Protected against dc short circuits to supply rails*

The TCA2465 consists of dual-power op amps housed in a 9-pin power single in-line package. Each op amp within the device is internally compensated and can supply peak output currents as high as 2.5A. They operate from supply voltages between  $\pm 3V$  and  $\pm 20V$ . The op amps are internally protected against output short circuits to either supply rail and against thermal overloads. Operating from  $\pm 10V$  supplies, the op amps have a minimum open-loop gain of 70 dB at 100 Hz, a minimum common-mode input voltage range from  $-10$  to  $+7V$ , and a typical slew rate of  $2V/\mu\text{sec}$ . Under the same conditions, the output voltage can typically slew to  $\pm 8.5V$  at 1 kHz for a  $4\Omega$  load. The short-circuit current is typically 1A. The permissible differential input voltage ranges from the negative to the positive supply rail. TCA2465, \$2.90; TCA2465A, a 16-pin DIP requiring external compensation, \$2.40 (1000).

**Siemens AG**, Zentralstelle für Information, Postfach 103, 8000 Munich 1, West Germany. Phone (089)

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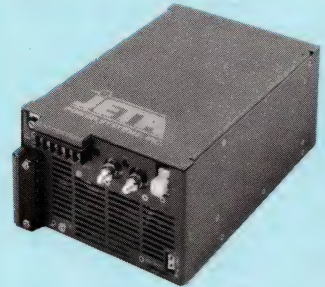
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See EEM pages D1706-1708



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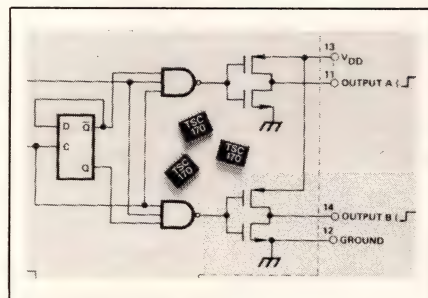
## INTEGRATED CIRCUITS

2340. TLX 5210025.

Circle No 403

Siemens Components Inc, 2191  
Laurelwood Rd, Santa Clara, CA  
95054. Phone (408) 980-4500.

Circle No 404



### CONTROLLER

- Features 3.8-mA max quiescent current
- Has dual totem-pole outputs

TSC170/171 CMOS switching regulator ICs run at one-fifth the quiescent supply current of the equivalent, bipolar UC3846/3847. The lower supply current eliminates the need for high-wattage power resistors in off-line switching topologies. You can employ the current-mode control to parallel two or more power supplies for higher-power applications. The controller's dual totem-pole outputs can directly drive power MOSFETs or bipolar transistors. The units' output voltage swing equals the supply voltage, and each output's 50-nsec rise and fall times (1000-pF capacitive load) minimize power dissipation in the MOSFET switches. Each unit also features an internal voltage reference and undervoltage-lockout and soft-start capability. When in the off state, the TSC170 has low outputs and the TSC171 has high outputs. In a 16-pin plastic DIP, \$4; in a 16-pin wide-body small outline package, \$4.25 (100).

Teledyne Semiconductor, 1300  
Terra Bella Ave, Mountain View,  
CA 94039. Phone (415) 968-9241.  
TWX 910-379-6494.

Circle No 405



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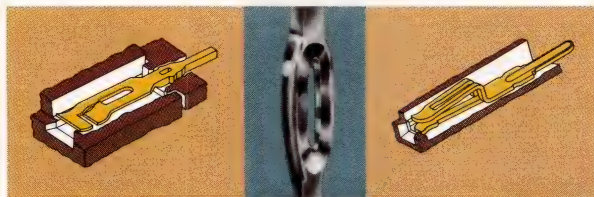
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EDN February 18, 1988

CIRCLE NO 213

263



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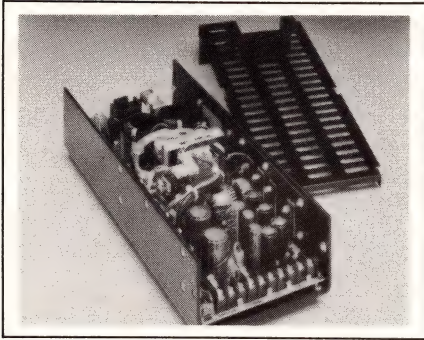
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# NEW PRODUCTS

## COMPONENTS & POWER SUPPLIES



### POWER SUPPLY

- Has isolated, fully regulated outputs
- Features a 5V/40A main output

The 300W Model NQF 300 features four fully isolated and regulated outputs that have better than  $\pm 1\%$  line, load, and cross regulation. Its transient recovery time equals 500  $\mu\text{sec}$  for 50% load steps, and its main output is preset to 5V/40A. You can specify any combination of 5, 12, 15, or 24V for the three auxiliary outputs; the current can range to 10A pk on output 2, and 5A on outputs 3 and 4. Each output has full overload and short-circuit pro-

tection. You can select input ranges of 90 to 132 or 180 to 246V ac, 47 to 440 Hz. The supply meets UL, CSA, VDE, IEC, and BS safety standards and contains VDE standard RFI line filters. \$345 (50).

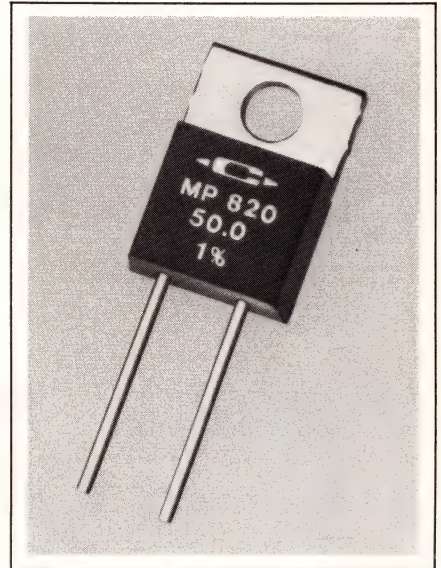
**Intelligence Power Technology Inc.**, 2111 Howell Ave, Anaheim, CA 92806. Phone (714) 937-1301.

Circle No 351

### POWER RESISTOR

- Housed in TO-220 power package
- Features  $\pm 1\%$  standard tolerance

Housed in a TO-220 power package, the MP820 Kool-Tab device is a 20W heat-sink-mountable power resistor. The resistor employs a noninductive design that makes it suitable for high-frequency and power-switching circuitry. Its resistance values range from 10 $\Omega$  to 1 k $\Omega$  and its standard tolerance equals  $\pm 1\%$ . The resistor features a silicone case, which protects it from the environ-



ment, and a low profile, which permits you to fit it into tight spots. Its single-screw mounting design simplifies the task of attaching it to a heat sink. \$1.90 (1000) for a 50 $\Omega$  device. Delivery, six weeks ARO.

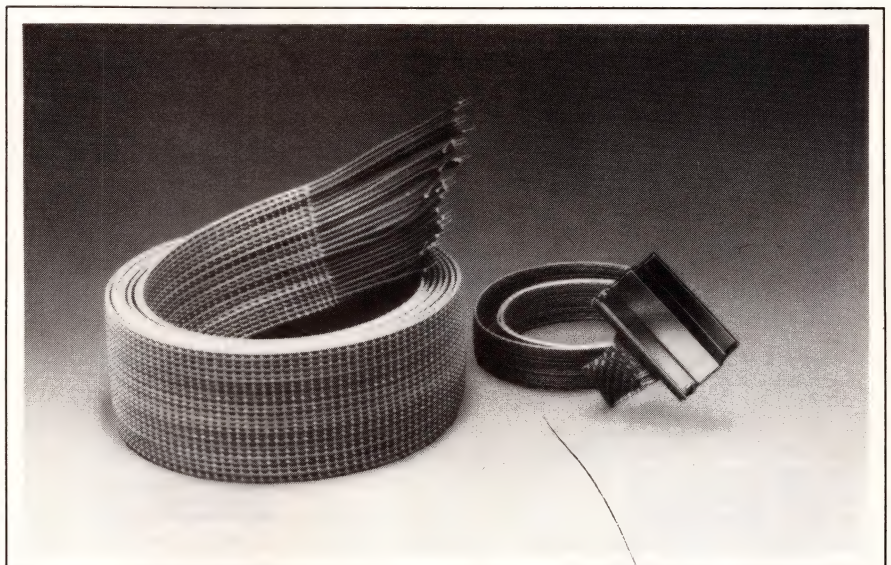
**Caddock Electronics**, 1717 Chicago Ave, Riverside, CA 92507. Phone (714) 788-1700. TWX 910-332-6108.

Circle No 352

### COAXIAL CABLE

- Highly flexible for easy bending, routing, and stowing
- Available with six to 64 signal conductors

This subminiature ribbon coaxial cable is highly flexible. You can fold the cable upon itself, bundle it in rectangular or round sections, or group it with other cable for routing. To terminate each signal set, you secure the signal conductor and companion drain wire to the appropriate connector terminals. The vendor can provide custom-designed multilayer paddle cards or pc boards to eliminate impedance mismatch. You can order the cable in varying lengths, with six to 64 signal conductors, single or dual drain



wires, and impedances of 50 to 130 $\Omega$ . \$1.25/ft (100 ft).

**Woven Electronics**, Box 667850,

Charlotte, NC 28266. Phone (803) 963-5131.

Circle No 353



## INTERRUPTER MODULE

- Consists of a GaAlAs emitter and a hybrid photodetector
- Features a built-in daylight-suppression filter

The SFH 910 differential photo interrupter module contains TTL-compatible circuitry that provides a counting pulse and a directional

pulse that let you detect the direction of motion. The unit consists of a GaAlAs IR emitter and a hybrid photodetector. The photodetector encompasses a split photodiode with amplifiers, Schmitt triggers, and evaluation logic; the module also features a built-in daylight-suppression filter. Both the counting-pulse and directional-recognition signals

are npn open-collector outputs compatible with TTL circuitry. You can use the module to encode mechanical-shaft rotation speed and direction. It accepts code wheels with slot widths as small as 0.85 mm. You can obtain a 96-slot code wheel as an option. SFH 910, \$5.60 (1000); disc, \$0.73.

**Siemens Components Inc.**, Optoelectronics Div, 19000 Homestead Rd, Cupertino, CA 95014. Phone (408) 725-3520.

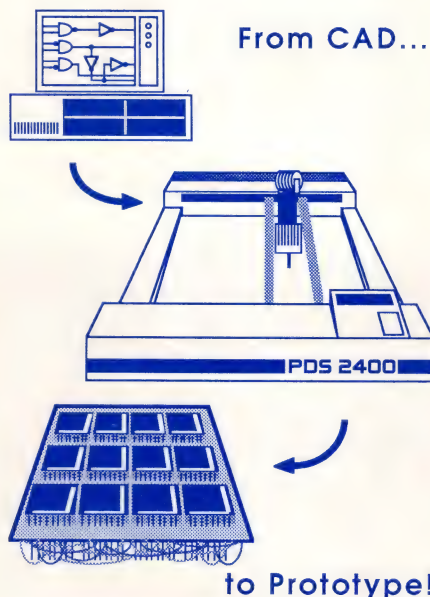
Circle No 354

## WORKING PROTOTYPES IN HOURS?

### DESKTOP AUTOMATED WIREWRAPPING

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Now you can turn your circuit designs into working prototypes in hours. The PDS 2400 automated wirewrapping system is small and quiet enough to fit in any environment.



#### Features:

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## RESISTORS

- Withstand 50 kV in air or 100 kV in oil
- Are available in 1, 2, or 5% tolerance levels

Produced by depositing a ruthenium oxide thick film onto a high-purity ceramic base, T40 Series high-voltage resistors can withstand a dc voltage as high as 50 kV in air or 100 kV when immersed in oil. The series includes three types with resistance values ranging from 1 kΩ to 4 GΩ, 1 kΩ to 15 GΩ, and 1 kΩ to 45 GΩ, respectively. The resistances are available with tolerances of ±1, ±2, or ±5% and temperature coefficients of ±25, ±50, or ±100 ppm/°C. A sleeve over the resistor protects it from mechanical damage and provides electrical insulation. From £3 to £10 (1000).

**Welwyn Electronics**, Bedlington, Northumberland NE22 7AA, UK. Phone (0670) 822181. TLX 53514.

Circle No 355

**IRC Inc.**, Box 1860, Boone, NC 28607. Phone (704) 264-8861. TLX 469902.

Circle No 356



# Mallory-brand Aluminum Electrolytics



## Selecting this outstanding capacitor line just became an even wiser decision.

**Because the company that makes them is now easier to work with.** When RTE bought Mallory's aluminum electrolytic business, they didn't change a great product. It's still made on the same production lines by the same skilled work force.

What did change was the level of customer service — at the plant and in the field — to make it easier for you to get specifications, samples or engineering help, and check delivery schedules. Now when we give you a shipping date, we meet it or beat it 99% of the time!

How has all this been accomplished?

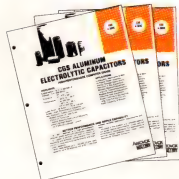
**At the plant,** by adding seasoned specialists, an in-

house CAD-assisted engineering department, and a computerized order entry/customer service expediting system.

**In the field,** by assigning all Aerovox M aluminum electrolytics to the service-driven rep and distributor organization of our sister RTE company, Aerovox Inc., one of the world's largest capacitor makers, and a leading supplier of EMI filters.

So, next time you need aluminum electrolytics, call your Aerovox rep, or us, direct... because our product is still outstanding. And now, so is our service!

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# NAVY SLASH SHEET POWER SUPPLIES



## NAVY STANDARD POWER SUPPLIES ARE HERE . . .

- Qualified By The U.S. Navy
- 100,000 Hour MTBF
- Reduced Acquisition And Life Cycle Costs
- Improved Maintainability
- Standard Navy Physical And Electrical Interfaces
- MOSFETS switched at high frequency

Navy Standard Power Supplies are now being mandated in Navy contracts. All Navy Standard Power Supplies meet general NAVSEA specification SE 010-AA-SPN-010, and appended slash sheets identify individual model characteristics.

EG&G Almond Instruments' **slash sheet** power supplies are being qualified by the Naval Weapons Support Center (NWSC), Crane, Indiana as part of the Navy Standard Power Supply program (SPSP).

For more information on the Navy SPSP and our 150 watt, 300 watt, and 750 watt SPSP Slash Sheet units, contact Dave Adams, Director of Marketing.

CIRCLE NO 46



**EG&G**

**ALMOND INSTRUMENTS**

1330 E. CYPRESS ST., COVINA, CA 91724 • (818) 967-9521 • TWX 910-584-1320

## COMPONENTS & POWER SUPPLIES

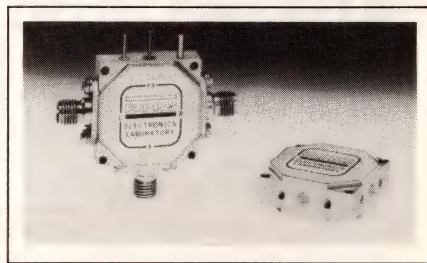
### DELAY LINES

- Available with a variety of impedance values
- Feature delays as long as 1000 nsec

Housed in 24-pin DIPs, the EPA059, EPA060, and EPA061 Series 20-tap delay lines provide 20- to 1000-nsec delays. Each unit has four 50Ω lines with 20- to 200-nsec delays, six 100Ω units with 20- to 1000-nsec delays, and five 200Ω devices with 20- to 1000-nsec delays. Nominal tap-to-tap delays for all three series are 1, 2.5, 5, and 10 nsec for 50Ω lines; 1, 2.5, 5, 10, 25, and 50 nsec for 100Ω lines; and 1, 2.5, 5, 25, and 50 nsec for 200Ω lines. Maximum output rise times range from 3 to 20 nsec for 50Ω units and 3 to 100 nsec for the 100 and 200Ω lines. All lines have their outputs on pin 23. Inputs are on pin 1 for the EPA060 units and on pin 2 for EPA059 and EPA061 Series devices. \$5.82 (1000) for the EPA059-100B, a 100Ω, 100-nsec total-delay unit with a 5-nsec/tap delay.

**PCA Electronics Inc.**, 16799 Schoenborn St, Sepulveda, CA 91343. Phone (818) 892-0761.

Circle No 357

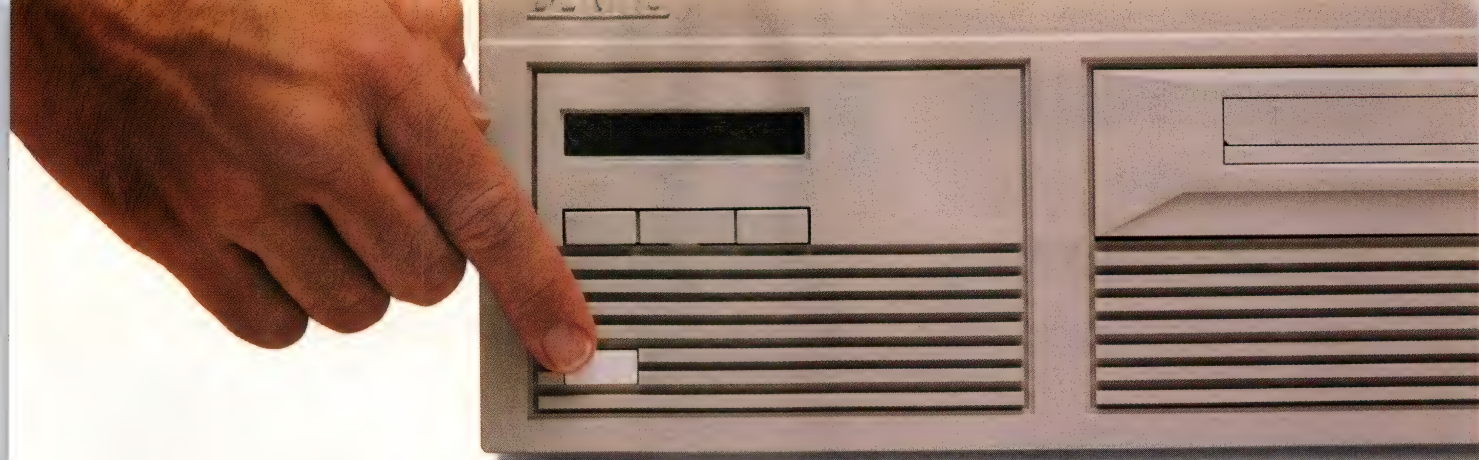


### MIXER

- Operates over 2- to 26-GHz range
- Housing has removable SMA connectors

The Model DBL2-26 biasable mixer operates over the 2- to 26-GHz range and provides IF signals from 1 to 500 MHz. It utilizes a self-adjusting bias arrangement in which the dc-bias level is reduced as the LO (local-oscillator) power is in-





# Push button backup.

Low-cost backup  
for HP9000 users.

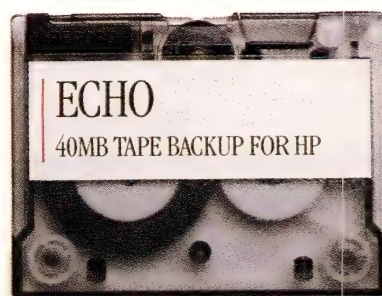
For all the times you've wanted a simpler, smarter, more reliable way to backup your data, Bering has the answer.

Introducing ECHO. Automatic tape backup you can count on time after time after time.

Our ECHO 40MB tape backup drive is compatible with all HP9000 Series 200/300/500 users. It incorporates the kind of sophisticated features you'd expect from an expensive drive. Yet it's priced at about *half* the price of comparable systems.

ECHO doesn't sacrifice quality, either. It's extremely reliable, with built-in error corrections that let you rest assured you're not missing anything.

At the push of a button, your ECHO drive can copy 40MB of data from your hard disk, creating a "mirror image" of your



files. Other features like off-line operation let you perform backup or restore without a CPU. ECHO's timed-backup lets you automatically backup a project without being present. Menu-driven selections and LCD displays make operation easier. And at 24MB per minute, ECHO's backup is *very* fast.

Last, but not least, ECHO uses the latest space-saving 3M DC2000 mini tape cartridges—a tidy little addition to over-crowded work areas.

For a data sheet or more information, call us at **800 BERING 1**. Bering Industries, 240 Hacienda Ave., Campbell, CA 95008.

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## New Instruments

### $\mu$ P-based Programmable E/I dc Calibrator



**Model 520/A**

The Model 520/A is micro-processor based and is compatible with IEEE-488, (GP-IP).

The height is only 3½ inches, features current mode outputs from 10 nanoamperes (nA) to 110 milliamperes (mA), in 2 ranges, with extraordinary compliance of 100 Vdc. Even with this power, ideal for transducer instrument testing (4-20 and 10-50 mA), the accuracy is  $\pm 0.005\%$ !

The voltage mode has 3 ranges with outputs from 100 nV to 110 Vdc and optional to 1100 Vdc. Compliance current is 100 mA. The one year accuracy is  $\pm 0.002\%$ .

All ranges and both modes resolve to 1 ppm. A crowbar zero provides a reference for this essential value.

**Availability:** 60 days.

**Price:** \$3,150. 1000V option \$595.

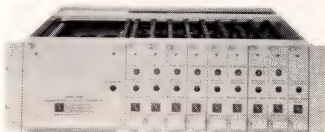
Engineering Contact: **Bob Ross**

Tel: (617) 268-9696

FAX: (617) 268-6754

**CIRCLE NO 89**

### AC Voltage Reference System Remotely Controlled Multiple Output



**System 408**

1 to 8 AC Voltage outputs independently and remotely controlled, variable and simultaneous in a single 5¼" high chassis.

A phase angle of 0° and 180° is also programmable.

All functions programmed via **IEEE-488 (GP-IB)** interface bus.

Some applications: Synthesize linear velocity sensors, simultaneous calibration of multiple instrumentation and data logging systems without multiplexing delays. Simulation of transducers. For design, evaluation and calibration of accelerometers, amplifiers, A/D converters, digital and analog meters.

Specifications include: Range: 10 mV to 30 Vac resolved to 1 mV. The compliance current is: 50 mA. The accuracy is:  $\pm (0.05\%$  of setting + 15 mV). Output frequency (synchronized to an external sine wave stimulus): at a selected, fixed frequencies between 10 Hz and 400 Hz.

**Price:** Main frame: \$3,995  
Output modules: \$895/each

Engineering Contact: **Bob Ross**

Tel: (617) 268-9696

FAX: (617) 268-6754

**CIRCLE NO 90**

**ELECTRONIC DEVELOPMENT CORP.**

11 Hamlin St., Boston, MA 02127

Tel: (617) 268-9696

TLX: 951596 (ELECDEVCO BSN)

# Programmable Joysticks.

## The Model 860 series of miniature force-operated controls.

Whatever your requirements, you can easily program the microprocessor controlled conversion of these joysticks for either an RS232 or RS422 port.

The Model 860 series, in fact, is designed for easy compatibility through most serial ports. And more.

With these controls, precise positioning is now easier than ever. The secret is built-in operator assistance, a dead band at null and an exponential transfer curve. Single-element positioning and high slew rates are both easily obtained.

There's a choice of standard or custom packages, too, with pushbutton or paddle switches.

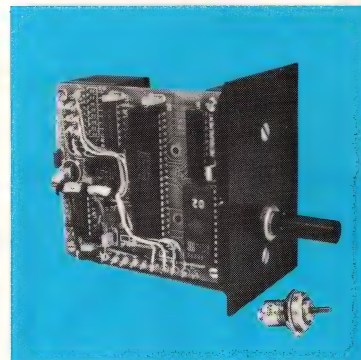
To program yourself for more information on these programmable joysticks, write or call:



**Measurement Systems, Inc.**

121 Water Street, Norwalk, CT 06854, U.S.A. (203) 838-5561

**CIRCLE NO 47**



## NEW!

### ThermaPro-V Technology for the Major DC and Patriot DC fans.



Introducing Major DC and Patriot DC with optional ThermaPro-V Technology.

High pressure capabilities for computer and telecommunications applications, combined with ThermaPro-V, make Major DC and Patriot DC a design engineer's answer to complex cooling problems.

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**CIRCLE NO 48**

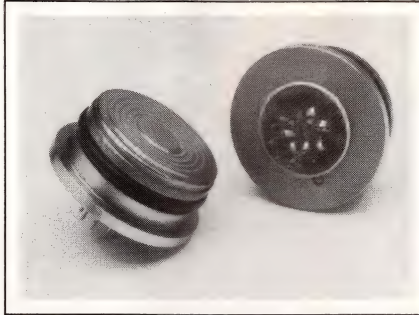


## COMPONENTS & POWER SUPPLIES

creased. It has a usable LO power range of 10 dBm. The typical conversion loss is 9 dB with 0 dBm LO power. The mixer requires a bias dc of 12V at 8 mA. It's also available for use at 15V. The mixer is supplied in a drop-in housing that features removable SMA connectors. The housing measures 1×1×0.375 in. \$1195. Delivery, 90 days ARO.

**RHG Electronics Laboratory Inc.**, 161 E Industry Ct, Deer Park, NY 11729. Phone (516) 242-1100. TWX 510-227-6083.

Circle No 358



ranges from 5 to 300 psi and in absolute ranges from 5 to 50 psi. Its accuracy is  $\pm 0.5\%$ . The unit has a stainless-steel housing, which uses silicone oil to couple a diffused piezoresistive sensor to a convoluted, flush, stainless-steel diaphragm. The diaphragm interfaces with most harsh media. Integral laser-trimmed resistors provide tempera-

### TRIMMERS

- Rated for 500 mW at 70°C
- Feature 1000-hour full-load life

The adjustable screw design of each CT-9 Series 18-turn trimmer resistor permits actuation of a worm gear that turns a wiper assembly around the trimmer's circular resistive element. The trimmers' resistance values range from 10 $\Omega$  to 5 M $\Omega$ . Their multicontact precious-metal wipers have low 1% contact-resistance variations. The trimmers are rated for 500-mW at 70°C and are derated to 0W at 125°C. Their other specs include a 300V dc max voltage rating, a 200-cycle rotational life, and a 360-g-cm shaft torque rating. Sealed with O-rings, the trimmers pass leak tests at 85°C and can withstand soldering temperatures of 350°C for as long as 3 sec. Their operating range spans -55 to +125°C. \$0.79 (5000).

**Mepcopal**, 11468 Sorrento Valley Rd, San Diego, CA 92121. Phone (619) 453-0332.

Circle No 359

### PRESSURE SENSOR

- Interfaces with most harsh media
- Temperature compensation over 0 to 50°C

The Model 84 pressure sensor is available in gauge and sealed-gauge



**Marconi is really moving with the fastest  
16 × 16 MAC available.**

We've combined low power consumption and the intrinsic rad-hardness of our CMOS/SOS with real-time image processing, real-time radar processing, computer graphics and digital communications.

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# MIL-STD-VME



## From the company that truly knows both military and VME

It took a company that knows both VME and military specifications to design and build the first fully militarized VMEbus boards. . . Plessey Microsystems. Only Plessey offers the totally VME-compatible PMV 68 family of modules for military environments. Processor boards. RAM, EPROM and EEPROM boards. Bubble memory. Even a board for interfacing the VME bus with the 1553B bus. Plus custom Mil VME capabilities.

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Each Plessey military VME board features MIL-STD-883C level B components to meet MIL-E-5400 (airborne), MIL-E-16400 (naval), MIL-E-4158 (ground mobile) and MIL-STD-810 (environmental) specifications. Other features include a

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Tel: (817) 261-9988

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CIRCLE NO 210

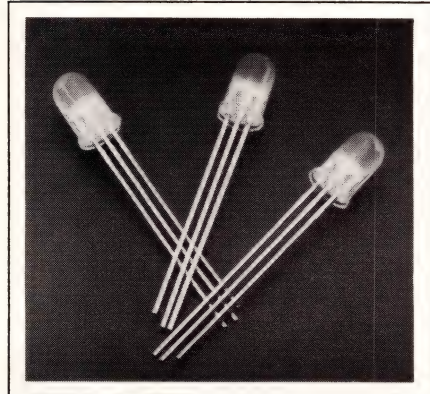


## COMPONENTS & POWER SUPPLIES

ture compensation and calibration over 0 to 50°C. For a 1.5-mA supply current, the nominal output span equals 100 mV. The device is  $\pm 1\%$  interchangeable. \$50 (OEM qty). Delivery, stock to six weeks ARO.

**IC Sensors Inc**, 1701 McCarthy Blvd, Milpitas, CA 95035. Phone (408) 432-1800.

Circle No 360



### 2-COLOR LEDs

- Combine red and green LEDs in one package
- Luminous intensities range to 8 mcd

Housed in a 3-lead, industry-standard T-1 $\frac{3}{4}$  package, HLMP-4000 bi-color LED lamps contain a red chip and a green chip. The leads are spaced on 0.05-in. centers, with the center lead providing the common-cathode connection. The viewing angle is 65°. The typical luminous intensity, at a 10-mA forward current, measures 5 mcd for the red chip and 8 mcd for the green chip. \$0.46 (10,000).

**Hewlett-Packard Co**, 1820 Embarcadero Rd, Palo Alto, CA 94303. Phone local office.

Circle No 361

### TRANSISTORS

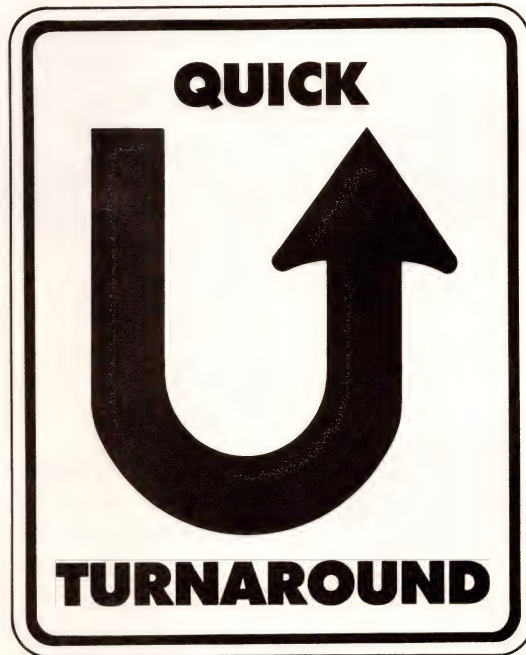
- Have collector breakdown voltages as high as 300V
- Maintain gain at high collector currents

The ZTX-554, -555, -556, and -557 are high-voltage medium-power pnp

transistors. The ZTX-554 and -555 have collector-emitter breakdown voltages of 125 and 150V, respectively; both have a gain of 50 to 300 at a collector current of 300 mA. Their maximum collector current equals 1A, and their power rating specs at 1W. The ZTX-556 and -557 have collector-emitter breakdown voltages of 200 and 300V, respec-

tively; both have a gain of 50 to 300 at a collector current of 50 mA. You can obtain all the devices in TO-92 cases. You can also order the ZTX-555 and ZTX-557 transistors in surface-mount packages that come on 16-mm tape for use with automatic placement equipment. \$0.17 to \$0.20 (1000).

**Ferranti Electronics Ltd**, Fields



### Tired of having to wait forever for rad-hard RAMS?

Call Marconi. We can deliver 1K to 16K rad-hard RAMS from stock fast. Made to meet MIL-STD-883C requirements for Class B devices, they also provide exceptional radiation hardness. Class S also available. For complete information on these, or any CMOS/SOS you need, call a Marconi sales engineer today at 516-231-7710.

- ☐ I'm interested in fast delivery of SOS RAMS. Please have a Marconi Representative contact me.

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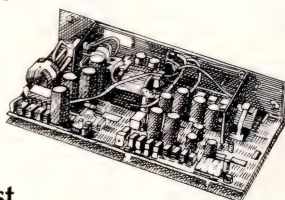
CIRCLE NO 50



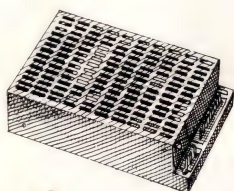
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TWX: 5101003630  
FAX: 617-655-7984

CIRCLE NO 51

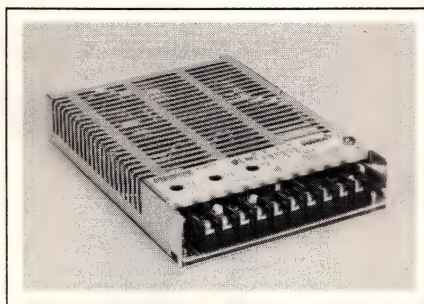
## COMPONENTS & POWER SUPPLIES

New Rd, Chadderton, Oldham,  
Lancashire OL9 8NP, UK. Phone  
061-624 0515. TLX 668038.

Circle No 362

Ferranti Electric Inc, 87 Modular  
Ave, Commack, NY 11725.  
Phone (516) 543-0200. TLX 6852104.

Circle No 363



### POWER SUPPLIES

- Offer power levels of 25 to 150W
- Feature 20-msec min holdup  
time

Housed in enclosures that are UL recognized and CSA certified, the 34 models in the Mustang series of switching power supplies provide output powers of 25, 50, 70/80, 100, and 150W. All models feature an input EMI filter, inrush-current limiting, output-voltage adjustment, built-in overload protection, and typical operating efficiencies of 70 to 75%. Low-line to high-line regulation equals 0.4% and no-load to full-load regulation equals 0.8%. All models have a 20-msec min hold-up time. From \$59.50 (1000).

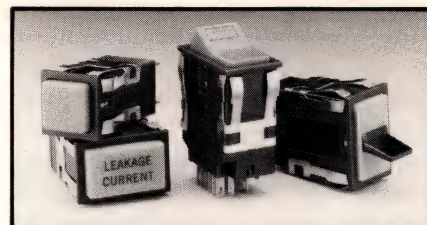
Computer Products Inc, 2900  
Gateway Dr, Pompano Beach, FL  
33069. Phone (305) 974-5500. TWX  
510-956-3098.

Circle No 364

### PRESSURE SENSORS

- Designed for hostile media in  
harsh environments
- Can sense from 15 to 300 psig

ST2000G Series pressure transducers are suitable for measurement of hostile media in harsh environments. Encased in rugged stainless-



### Solid state AML manual controls

A Hall effect integrated circuit is the key to reliability and long life in these solid state pushbuttons, rockers, and paddles from the industry standard AML line. Simple to install and easy to wire, they can interface directly with microprocessors and other types of logic level circuitry.

These manual controls are designed with human factors in mind. For wide angle visibility, LED lighting is available. A variety of colors and legends offer additional design flexibility.

These products are UL and CSA recognized, and feature an 18-month warranty.

For more information or a FREE catalog covering our full line of manual controls, write MICRO SWITCH, Freeport, IL 61032. Or call 815-235-6600.

CIRCLE NO 108



### Compact size, up to 4-poles

These tactile feedback and short travel pushbutton switches from the PB Series have a display area of just .32", making them ideal for tight spaces. Yet they can incorporate up to four SPDT circuits.

Touch feedback PBs use a spring loaded actuator. To reduce travel and operating force, the short travel version uses a leaf spring actuator. Momentary action is provided.

These switches feature round-hole mounting and handle up to 11 amps. Buttons are available in black, red, and green for design flexibility.

For more information or a FREE catalog covering our full line of manual controls, write MICRO SWITCH, Freeport, IL 61032. Or call 815-235-6600.

CIRCLE NO 109



Reducing your product costs  
could be as simple as  
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**MICRO SWITCH**  
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steel packages, the transducers each feature an IC sensor element and signal-conditioning circuitry. They have pressure-sensing capability that ranges from 15 to 300 psig (pressure per square inch of gravity). You can obtain the transducers with either 1 to 6V dc or 2.5 to 12.5V dc for each pressure range. Their sensor output options include

full-scale spans of  $5V \pm 200$  mV, and zero-pressure offsets, trimmed to within  $\pm 100$  mV, that allow you to interchange transducers without recalibrating. All the transducers feature temperature compensation to within  $\pm 0.02\%/^{\circ}\text{C}$ . The sensors are optimized for 0 to  $70^{\circ}\text{C}$  operation but will operate from  $-40$  to  $+85^{\circ}\text{C}$ . The transducers' operating

voltage ranges from 12 to 30V dc. \$125.

**Sensym Inc.**, 1255 Reamwood Ave, Sunnyvale, CA 94089. Phone (408) 744-1500.

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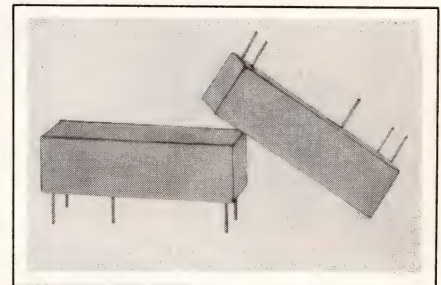
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### FILTERS

- 150- to 200-MHz frequency range
- Ripple is 1 dB max

The units in this line of LC filters feature a 4-pole response with a nominal frequency range of 150 to 200 MHz. Typical 3-dB bandwidths of  $\pm 10$  MHz are available; units are also available with a 50-dB bandwidth of  $\pm 60$  MHz. The operating range spans  $-35$  to  $+85^{\circ}\text{C}$ . The filters have 1 dB max ripple and 4 dB max insertion loss. The standard source and load impedance is  $50\Omega$ . From \$115.

**Piezo Technology Inc.**, Box 7859, Orlando, FL 32854. Phone (305) 298-2000. TWX 810-850-4136.

**Circle No 366**



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- 10,000-ft transmission capability
- 0.3% min accuracy

This fiber-optic module transmits 4- to 20-mA or 0 to 10V dc analog signals. Its transmission range is 10,000 ft. The optical encoding of data is based on signal frequency and is therefore not subject to error



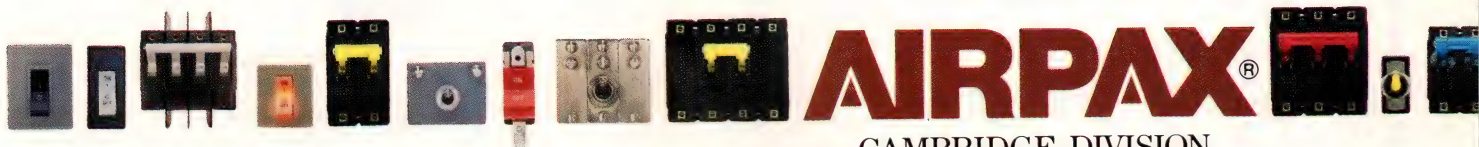
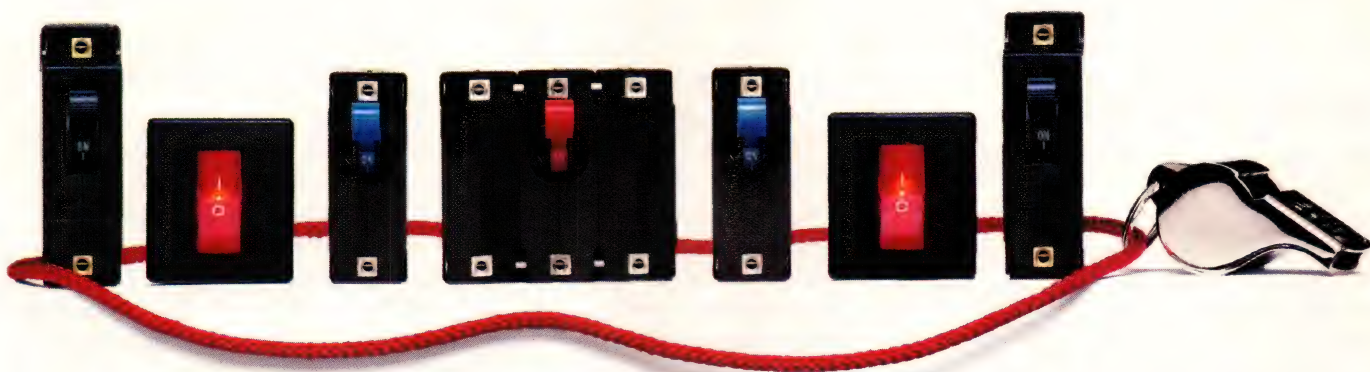
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caused by fluctuations in the received optical power. The link has a minimum accuracy of 0.3% and a response time of 2 msec max. The transmitters have LED indicators for power, overrange, and under-range signals. The receivers have LEDs and open-collector outputs to indicate overrange and lock conditions; the lock condition indicates that the receiver is accepting valid signals. \$900/pair.

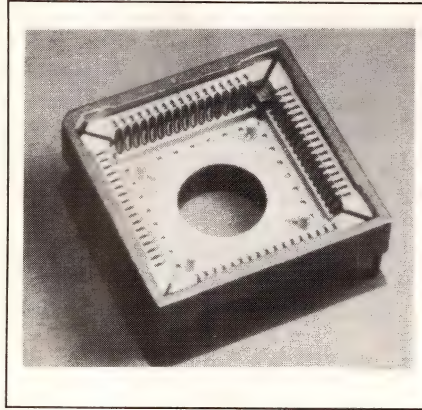
**EOTec Corp**, 420 Frontage Rd, West Haven, CT 06516. Phone (203) 934-7961.

**Circle No 367**

## BURN-IN SOCKETS

- Available in 20- to 68-position versions
- Feature housings rated for 200°C operation

These low-insertion-force, burn-in sockets come in 20- to 68-position



versions. They accept square, plastic chip carriers with J leads on 0.05-in. centers. The units feature liquid crystal polymer housings rated for continuous operation at 200°C. You can obtain them with three types of contacts: beryllium copper rated to 200°C, beryllium copper rated to 150°C, and phosphor bronze rated to 125°C. The contacts feature nickel-boron platings. The sockets have metal-locking frames that reduce insertion

forces, and positive ejection systems that facilitate manual or automatic loading and unloading and that also improve heat exchange. Their insertion life specs at 5000 cycles min. From \$8, depending on model and quantity.

**Mark Eyelet Inc**, 63 Wakelee Rd, Wolcott, CT 06716. Phone (203) 756-8847. TWX 510-600-7291.

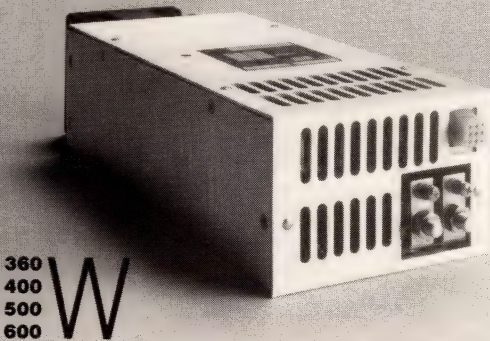
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- Designed primarily for field installation
- Feature a short-circuit failure mode

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**CIRCLE NO 208**

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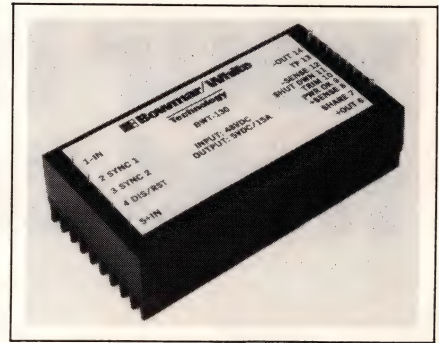


vices with operating line voltages of  $\pm 12$ ,  $\pm 25$ ,  $\pm 28$ ,  $\pm 36$ ,  $\pm 50$ , and  $\pm 60$ V max; the maximum clamping voltages (at 2000A) spec at 22, 44, 46, 60, 80, and 95V, respectively. You can make electrical connections easily, using two screws for line connections and three fork terminals for equipment connections. The suppressors feature a short-circuit

failure mode. Their maximum standby current equals 5  $\mu$ A and their line throughput resistance specs at 12 $\Omega$ . All the suppressors operate from  $-55$  to  $+100^\circ\text{C}$ . From \$24 (100).

**General Semiconductor Industries Inc.**, 2001 W Tenth Pl, Tempe, AZ 85281. Phone (602) 968-3101.

Circle No 369



## DC/DC CONVERTER

- Delivers 5V at 15A
- 400-kHz switching frequency

The Model BWT-130 switch-mode dc/dc converter converts an unregulated 48V dc input to a regulated 5V output at currents ranging to 15A. The converter has a 5.7 W/in.<sup>3</sup> power density and an 80% min efficiency. The fixed-frequency operation is 400 kHz, and the noise is less than 0.5% p-p from dc to 20 MHz. Other features include a 0.2% max load regulation, 0.1% max line regulation, overvoltage protection, current limiting to 18.8 A, 2000V dc min input-output isolation, and a typical no-load power consumption spec of 0.5W. The operating range, with natural convection, spans  $-20$  to  $+60^\circ\text{C}$ . \$300.

**Bowmar/White Technology Inc.**, 4246 E Wood St, Phoenix, AZ 85040. Phone (602) 437-1520.

Circle No 370

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tors, backplane assemblies & headers QPL'd to MIL-C-28754, telephone module plugs & jacks, as well as "D" subminiature crimp and board side connectors & assemblies.

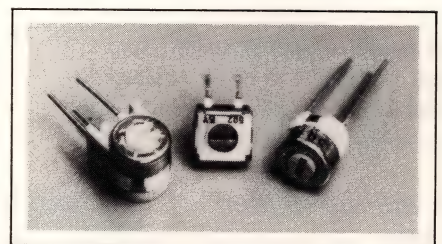
For additional information write: INTERCONNECT SYSTEMS DIVISION, MICRODOT INC., 201 Progress Drive, Montgomeryville, PA 18936, (215) 699-5373. TWX: 510-661-8206.



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MICRODOT INC.

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CIRCLE NO 55



## TRIMMERS

- Designed for high-density applications
- Sealed to withstand board-washing processes

The RJ-4 and ST-4C are single-turn, cermet trimmers. The RJ-4 is housed in a TO-18-type package, which measures 0.193 $\times$ 0.177 in. It



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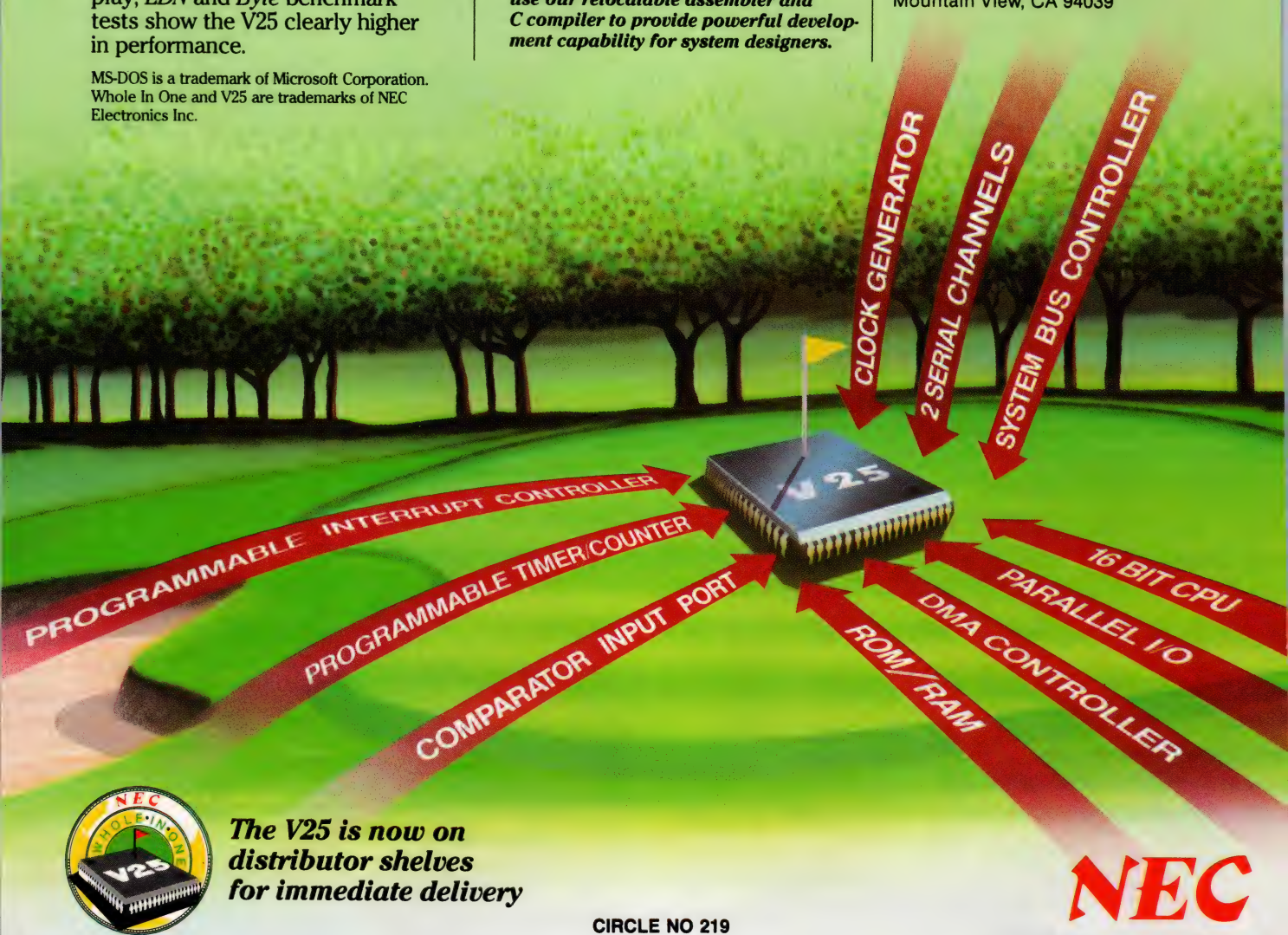
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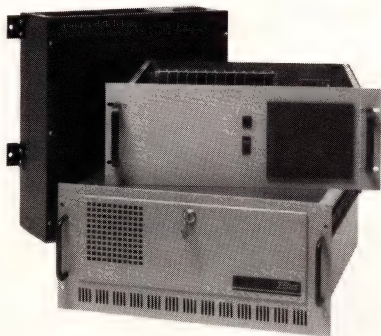
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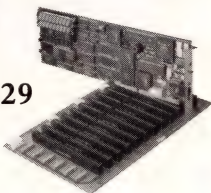
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**CIRCLE NO 56**

## COMPONENTS & POWER SUPPLIES

has a power rating of 500 mW and is available in top- or side-adjust configurations. The ST-4C measures  $0.177 \times 0.197 \times 0.091$  in. It's available with top adjustment. Both trimmers have a resistance range of  $10\Omega$  to  $2\text{ M}\Omega$  and a standard tolerance of 20% (10% tolerance is available). Both of them also have a 1% max CRV (contact-resistance variation) and are sealed with an O-ring, which enables them to withstand a variety of board-washing procedures. RJ-4, \$1.10; ST-4C, \$0.77 (1000).

**Mecopac Co.**, 11468 Sorrento Valley Rd, San Diego, CA 92121. Phone (619) 453-0332.

**Circle No 371**

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- *Come bundled with an enhanced version of Smartkey*

G80-2000 Series keyboards have an identical layout to the IBM 3270 keyboard, with 24 function keys along the top and 10 keys on the left. Normally, only software written for the 3270 recognizes the extra function keys. However, the vendor's keyboards come bundled with an enhanced version of Smartkey so that users of IBM PC/XT, PC/AT, or compatible computers can take advantage of the extra keys. You can obtain N-key rollover, LED actuation-indicators, and programmable autorepeat as options. You can order the keyboards with a low-profile housing that conforms to DIN standards. All the keyboards come with US/International, French, and German character layouts. You can also obtain custom versions of the keyboard that offer other layouts. \$900 with all options.

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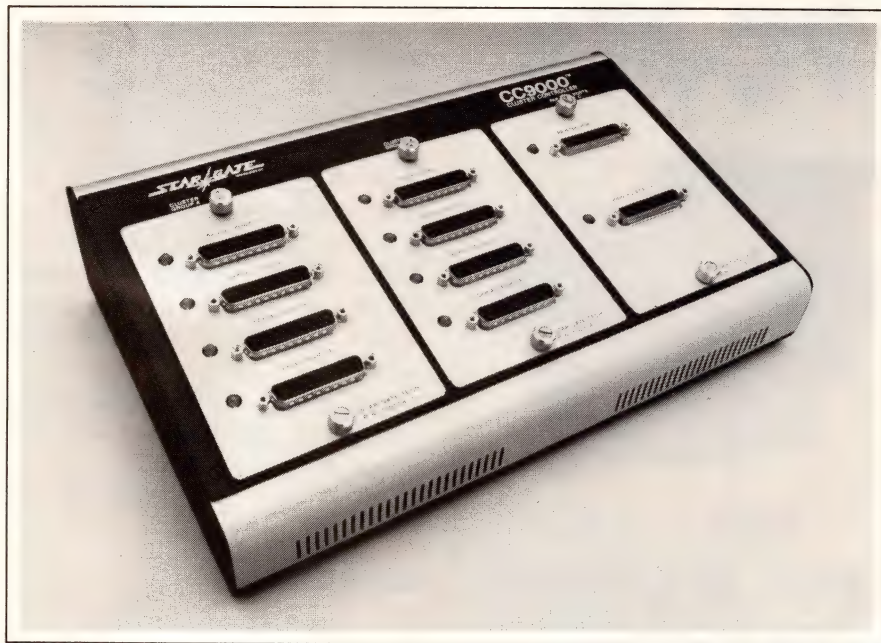
# NEW PRODUCTS

## COMPUTERS & PERIPHERALS

### CLUSTER CONTROLLER

- Can control 10 devices 800 ft from a PC
- An 80186 offloads I/O tasks from the host CPU

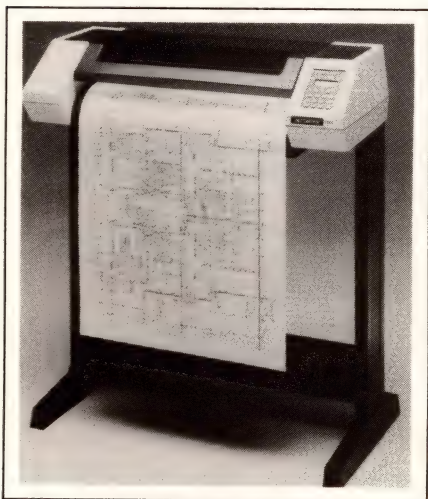
The CC9000 is an 80186-based communications control device. It provides eight serial and two parallel ports and can control devices located as far as 800 ft from the host PC. Since the host connection is compatible with a StarLAN interface, you can connect each unit to the host via a StarLAN hub or minihub interface card. The unit handles full-duplex operations and programmable baud rates from 50 to 38.4k baud. The host connection takes place via inexpensive, unshielded twisted-pair telephone wire. Using its  $\mu$ P, 512k bytes of RAM, and proprietary system software, the unit offloads some of the I/O tasks from the host. It supports



PCs and terminals running the MS-DOS-compatible PC/MOS/386 multi-user operating system from Software Link. 8-port unit, \$1295; upgradable 4-port unit, \$1295.

**Star Gate Technologies Inc.**, 33,800 Curtis Blvd, Eastlake, OH 44094. Phone (800) 782-4283; in OH, (216) 951-5922.

Circle No 407



### PEN PLOTTER

- Organizes plot data to minimize pen movements
- Plots at 30 ips on axis at a 2g acceleration rate

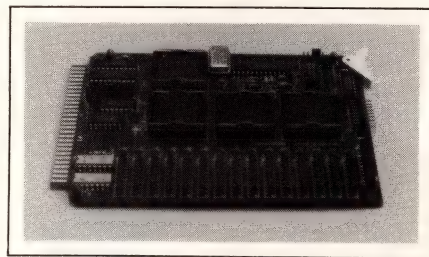
The 1023 pen plotter provides a plotting speed of 30 ips on axis at a 2g acceleration rate; its diagonal

plotting speed is 42 ips diagonally at a 2.8g acceleration rate. A look-ahead feature keeps the pen moving at high speed when a line changes direction by  $<45^\circ$ . One of its two 68000  $\mu$ Ps controls servo motion and linear pen motion, and the other controls data communications and management. Communications take place via an RS-232C interface with speeds to 19.2k baud. A data-management algorithm organizes plot data to minimize pen movements and pen changes. The algorithm searches the data structures stored in memory to plot the vector closest to the current pen position. An 8-pen rotating turret gives you a choice of eight colors or pen types. An optical sensor determines the type of pen selected and automatically adjusts pen force and velocity. Adjustable pinch rollers can handle media sizes from 8.5 $\times$ 11 in. to 25 $\times$ 36 in. The plotter also has an

MTBF of 3000 hours. \$4895.

**CalComp**, 2411 W La Palma Ave, Anaheim, CA 92801. Phone (714) 821-2142.

Circle No 408



### GRAPHICS BOARD

- Color graphics board for STD bus has an ACRTC processor
- Board attains drawing speeds of 2 million pixels/sec

The HRG-1000 is a color graphics board for the STD bus that features a Hitachi ACRTC graphics processor. The board can attain draw-



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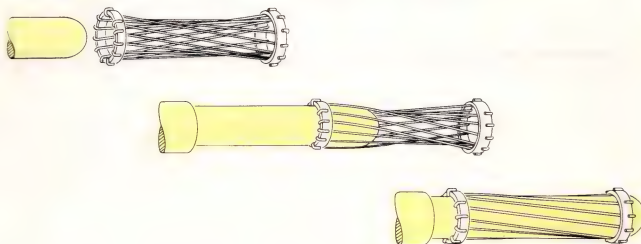
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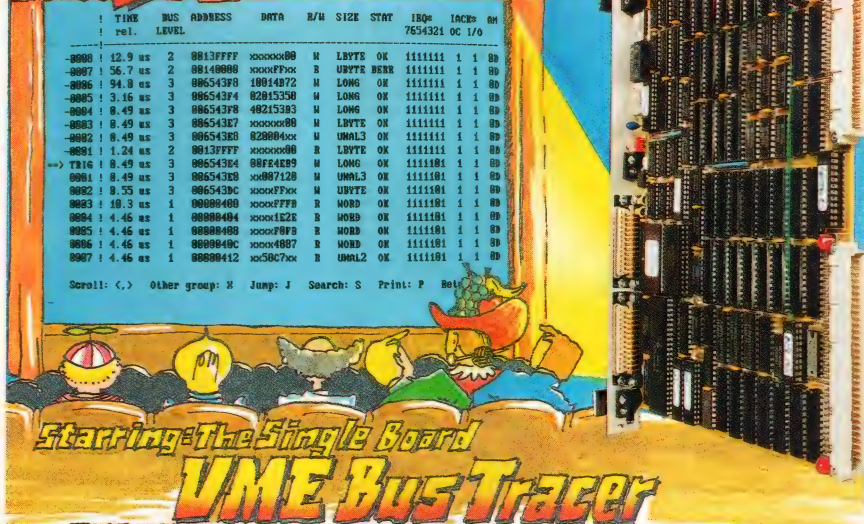
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CIRCLE NO 58

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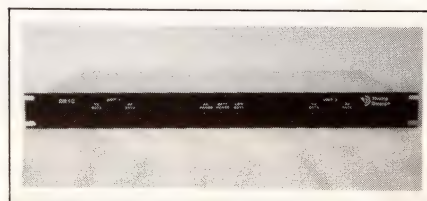
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## COMPUTERS & PERIPHERALS

ing speeds of 2 million pixels/sec. When used with an analog monitor, it can provide 16 simultaneous colors from a palette of 4096 colors. The board also works with TTL RGB input color monitors that have resolutions ranging from 320×200 pixels to more than 800×600 pixels. It includes 25-MHz and 32-MHz video output clocks and is programmable for the number of horizontal pixels, the number of lines, and synchronization rates. The board supports multiple screens, panning, zooming, windows, clipping, and more than 20 high-level drawing commands including lines, rectangles, polylines, polygons, circles, ellipses, and arcs. The board occupies an 8-byte block in the I/O or expanded I/O space. It requires 5V at 2.2A typ. \$664.

Cobra Systems, 14,700 Main St, Suite 3, Bellevue, WA 98007. Phone (206) 641-2759.

Circle No 409



## JITTER REMOVER

- Removes jitter on data from a master port
- Distributes reconditioned data to four ports

The DR-10 removes jitter from asynchronous data present on a master port and redistributes it to four auxiliary ports. It also removes jitter on data received from any of the four auxiliary ports prior to sending the data to the master port. All ports are RS-232C compatible and the redistributed data is time delayed by one byte. The unit operates full duplex at data rates from 300 to 9600 bps. The master port is configured as DCE (data communications equipment) and the auxiliary ports are configured as DTE



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Chicago, IL 60630

EDN021888



(data terminal equipment) to allow transparent insertion of the device in an RS-232C line. You can install one or two independent channels in a 1¾-in. standard 19-in. rack enclosure. The unit also has a battery backup option that powers the unit for more than 10 hours when ac power is removed. Single-channel unit, \$1195; dual-channel unit, \$1695.

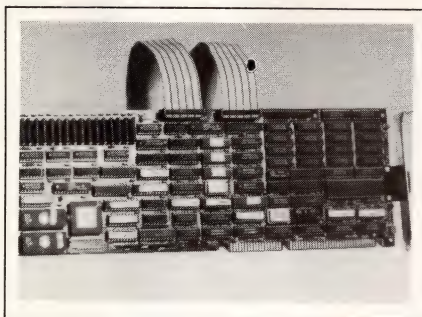
**Young Design Inc.**, 7882 Tyson Oaks Circle, Vienna, VA 22180. Phone (703) 448-8939.

**Circle No 410**

## FRAME STORE

- 1024×2048-pixel logical resolution
- Provides onboard color-image processing

The FS1000 Frame Store board provides IBM PC/ATs and compatible computers with image-processing



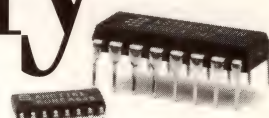
capabilities. The board is based on a 68010  $\mu$ P; it has 2M bytes of video RAM and a Brooktree Bt453 color palette IC that provides as many as three overlay colors and displays as many as 256 colors from a palette of 16M colors in the video image. On-board image-processing capabilities include image compression, zoom, and scrolling. The device sends the image to a standard RGB color monitor. Address mapping in the video RAM allows you to position single or multiple images anywhere on the screen. The text/graphics overlay facility allows you to add informa-

tion to the screen without destroying the video-image information. A software library of image-processing routines is available for the board. To expand the board's image-processing capabilities, you can link it to a Data Translation (Marlborough, MA) DT7020 32-bit floating-point array processor, via the Data Translation DT-connect bus. This connection lets you avoid using the PC/AT bus to transfer information between the two boards. The vendor is developing a piggyback frame grabber for the board. The FS1000 comes in two versions: one for use with NTSC color signals, one for use with PAL color signals. It costs \$4995, including a manual and sample programs.

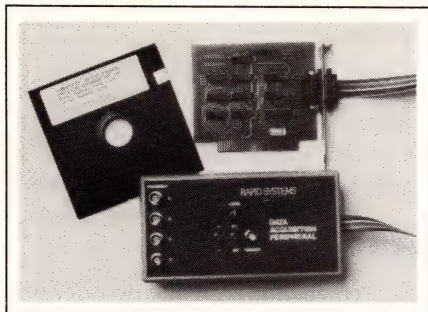
**Camtel Computer Systems Ltd.**, Unit 101, Cambridge Science Park, Milton Rd, Cambridge CB4 4FY, UK. Phone (0223) 61506. TLX 94012250

**Circle No 411**

# Samsung's Advanced CMOS Logic Family







## PERIPHERAL DEVICE

- Offers 4-channel data acquisition for IBM PC or compatibles
- Acquires data at 1- to 500-kHz sample rates

The R414 peripheral device for the IBM PC provides four data-acquisition channels. Its sampling rates range from 1 to 500 kHz, and its 8-bit A/D converter triggers on an internal or external analog signal. You can adjust the unit's gain so that the analog-input-voltage range spans 10 mV to 320V p-p. All of the unit's inputs have diode protection.

The unit comes with user programs and subroutines written in C, Turbo Pascal, or Basic. You can obtain software that lets you operate the unit as a digital oscilloscope or spectrum analyzer; digital-signal-processing hardware is also available. \$295.

**Rapid Systems**, 433 N 34th St, Seattle, WA 98103. Phone (206) 547-8311. TLX 265017.

Circle No 412



## COLOR MONITOR

- Has automatic frequency scanning
- Provides graphics resolution to 800x600 pixels

The Spectrasync 1437 is a color monitor with automatic frequency scanning from 15.5 to 37 kHz horizontally and from 50 to 90 Hz vertically. The monitor automatically adjusts the aspect ratio (the horizontal

and vertical dimensions and positions) to preset values. This adjustment allows the monitor to maintain the image on the screen at the desired size regardless of the scanning frequency. The monitor can be used with the IBM PS/2; the IBM PC, PC/XT, PC/AT, and compatibles; and the Apple Macintosh II. It supports IBM's CGA, EGA, PGA, VGA, and MCGA graphics stand-

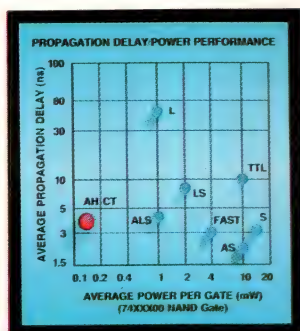
## How to stay current on glue logic.

Samsung's Advanced AHCT CMOS Logic Family meets the demands of your new 16- and 32-bit designs for high speed, high drive and low power.

**Available now.**

Our Advanced AHCT CMOS Logic Family has a selection of 109 part types available in production quantities now, increasing to 157 parts by 2Q '88. This means you can design AHCT into your product now and move immediately into production.

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KS74AHCT PARTS LIST

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01 21	74 534	243* 646 659*	153 257
02 22	76 564	245 648 661*	157 262
03 27	78 574	640 651*	158 352
04 30	107 670	643 652*	251 353
05 32	109 794*		
08 51	112 821*		
09 58	173 822*		
10 86	174 823*	Counters	Shift Registers
11 132	175 824*	160 169 390*	164 299*
12 133	273 825*	161 190 393	165 595
14 266	374 826*	162 191 590*	166 596
		163 192 591*	194 597
		168 193 592*	
			593*
Buffers & Line Drivers	Latches	Decoders/Encoders	Arithmetic Circuits
125 367	75* 793*	42 148* 238	181* 522*
126 368	77* 841*	138 154 239	182* 679
210 465*	259 842*	139 155	183 680
240 466*	373 843*		280 682
241 467*	533 844*	Multivibrators	518* 684*
244 468*	563 845*	121* 123* 423*	519 686*
365 540	573 846*		520* 688
366 541			521 689*
			Logic Level Converters
			4049 4050*

\*Part types available in 2Q '88. All other part types available now.

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CIRCLE NO 59

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CIRCLE NO 60

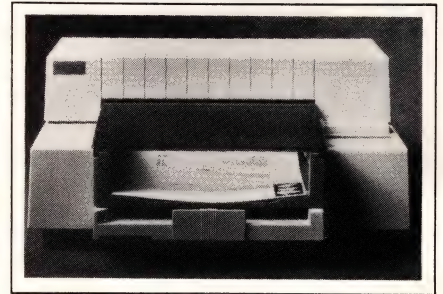
For 5x8x11 "slot" switching power supplies from 750 to 2000 Watts, the Qualidyne Case 10 is all you need to know. MTBF of 150,000 hours. Single or multiple (up to 5) fully regulated outputs from 2 to 48 VDC. Precision paralleling for N+1 redundancy. AC and DC input voltages. Safety listings from UL, CSA and TUV. Compliance with IEC 380 & VDE 0806. FCC 20780 Class A filtering. Nothing fancy, just reliable slot power—period.

## COMPUTERS & PERIPHERALS

ards and can accept TTL digital or analog video inputs. The 14-in. diagonal screen has a 0.31-mm pitch and provides graphics resolutions as high as 800×600 pixels. Three front-panel RGB pushbuttons let you select from seven text colors. When all three buttons are off, the display is monochrome. An optional tilt/swivel base is available. \$849. Tilt/swivel option, \$29.

**Idek America Inc**, 204 S Olive St, Rolla, MO 65401. Phone (314) 364-7500.

CIRCLE NO 413



### PRINTER

- Provides laser-quality output for \$995
- Prints text at speeds of 120 cps

The DeskJet is a personal printer with laser-quality output. It employs inkjet technology, but prints high-resolution text and full-page graphics at 300 dots/in. It prints text at speeds of 120 cps for laser-quality text and 240 cps for draft quality. The printer features an automatic cut-sheet feeder (to 100 sheets) and a front-loading design for quick reloading of paper. It can accommodate US letter, legal, and European A4 paper sizes, as well as manually fed #10 business envelopes. The printer has Courier, Courier Bold, and Courier Compressed fonts built in. Two accessory-cartridge ports extend the available font types. These ports also provide memory expansion (to 256k bytes of RAM) for soft fonts and provide an interface for an FX-80 printer emulation cartridge. The printer has a 16k-byte buffer and

# ENCODER



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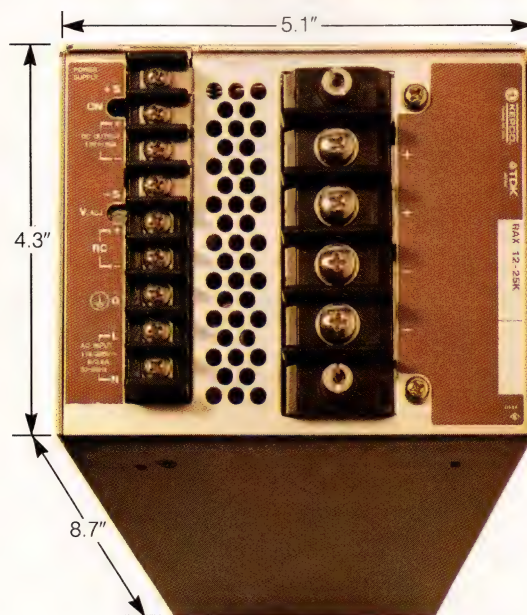
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# New 150KHz switcher. 4.3 inches high. 50 to 1500 Watts. SELV. And loaded.

- 8mm primary-secondary and 4mm primary-ground spacings for a SELV (Safety Extra Low Voltage) power supply per IEC 380/VDE 0806. UL recognized, CSA certified. VDE/IEC certified by TÜV Rheinland.
- On-board dual-choke filter meets FCC Class A.
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  - Power on LED. ■ Remote on/off, optically isolated.
  - Remote error sensing. ■ Voltage adj +10, -30%.
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  - 300V d-c input. ■ Current share (1500W).
- The 300W and 1500W models have undervoltage protection.
  - Holding time: 20msec. min, 30msec typ.
- Supplied fully enclosed for industrial applications.

**All built-in. No extra cost.\***



Shown:  
300-Watt Model  
RAX 12-25K  
(Output 12V/25A).

**\*Price complete:**  
50W — \$199  
100W — \$289  
175W — \$380  
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Belden Wire And Cable,  
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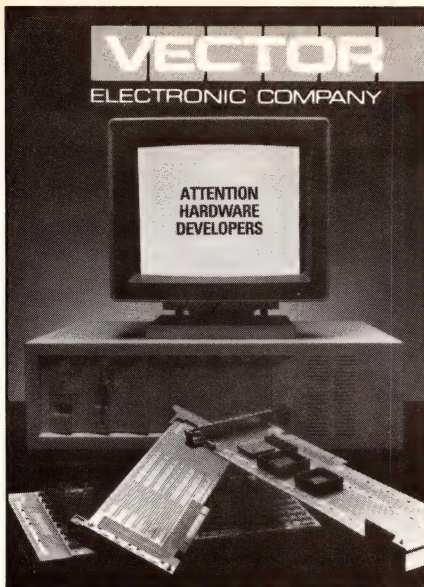
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**CIRCLE NO 203**

3-1-5A







## WHAT'S NEW FOR THE IBM PS/2

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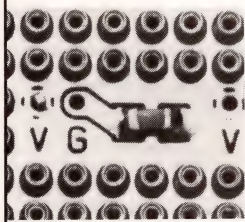
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124

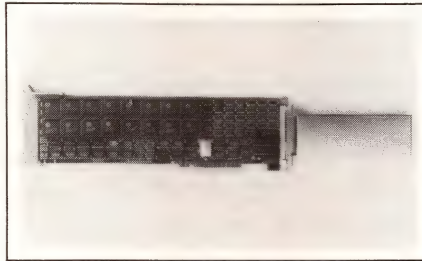
CIRCLE NO 62

## COMPUTERS & PERIPHERALS

employs the company's PCL printer language. Either an RS-232C or a Centronics parallel port serves as the computer interface. \$995.

**Hewlett-Packard Co.**, 1820 Embarcadero Rd, Palo Alto, CA 94303. Phone local office.

Circle No 414



### COMMUNICATION BOARDS

- Provide either eight or 16 serial ports for the IBM PS/2
- Feature communications for multiuser operating systems

PS-COM/X Series boards for the IBM PS/2 models 50, 60, and 80 feature either eight or 16 asynchronous serial communications ports per board. You can mount as many as four of these 16-channel boards on the PS/2 Bus to provide 64 serial ports. You can select data-transfer rates from 50 to 56k baud for each port. The boards use high-speed 16450 UARTs and are compatible with the DOS, OS/2, Xenix, Unix, Theos, Pick, QNX, and PC-MOS operating systems. Each port provides full modem control. You can mount as many as 16 RJ-45 connectors in a compact, shielded extension that mounts on the faceplate connector extending from the board. The connector allows you to use multiple boards in a system that has either RJ-45 or RJ-11 cabling. COMware software allows DOS to access as many as 64 COM ports. 8-port version, \$895; 16-port version, \$1295.

**DigiBoard Inc.**, 6751 Oxford St, Saint Louis Park, MN 55426. Phone (800) 344-4273; in MN, (212) 922-8055.

Circle No 415

## C MODULA 2 PASCAL

### Cross-Compiler Systems

- High performance, field-proven software development systems producing extremely compact, fast-executing, ROMable output code.
- Each cross-development package includes:
  - C, Modula 2, or Pascal Cross-Compiler
  - Macro Relocating Cross-Assembler
  - Object Code Librarian
  - Object Module Linker
  - Hexadecimal Format Loader [S-Records, Intel Hex, TEK Hex]
  - Standalone Support Library [EPROMable, with full floating point support]
- All languages can be intermixed with assembly language

- Targets supported:

**6301/03**  
**6801/03**  
**6809**  
**68HC11**  
**68000/08/10/12**  
**68020/881/851**  
**32000/32/81/82**

- Available for following hosts:

VAX: VMS/UNIX/ULTRIX  
PDP-11: UNIX/TNIX/VENIX  
68000: UNIX System V  
PC,XT,AT: MS-DOS  
PowerNode: UTX/32

UNIX: TM of AT&T Bell Labs.  
VAX, VMS, PDP-11, ULTRIX:  
TM of Dig. Equip. Corp.  
TNIX: TM of Tektronix Inc.  
VENIX: TM of VenturaCom  
PowerNode; UTX/32: TM of Gould Inc.

**INTROL CORPORATION**  
**647 W. Virginia Street**  
**Milwaukee, WI 53204**  
**(414) 276-2937**  
**FAX: (414) 276-7026**

CIRCLE NO 63



## RAM BOARD

- Provides 4M bytes of iLBX-II memory for Multibus II systems
- Has a refresh mode suited to video acquisition

The FAB104 Multibus II-compatible memory board provides 4M bytes of parity-checked dynamic RAM, which is sent to an iLBX-II bus on its P2 connector. The board supports 8-, 16-, 24-, and 32-bit data transfers, and 26-bit addressing on the iLBX-II bus. It has a read-access time of 375 nsec and a write-access time of 250 nsec. You can program a variety of board parameters—including its base-address and refresh modes—via the Multibus-II interconnect space, which is supported on the iLBX-II bus. One of the board's refresh modes is designed to allow the board to acquire video information and support image-processing operations in real time. The board typically draws

3.5A from its 5V supply. FrFr 34,200.

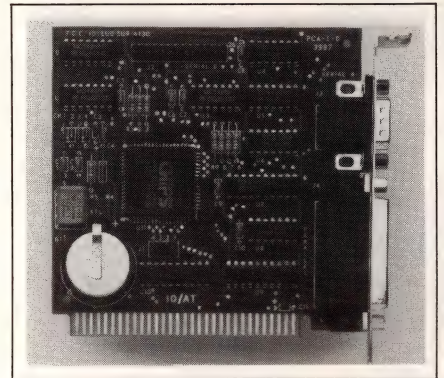
**Centralp Automatismes**, 16 rue Gabriel Peri, 92120 Montrouge, France. Phone (1) 42533617. TLX 632380.

Circle No 416

## I/O BOARD

- Provides a serial and a parallel port
- Serial port is addressable as either COM1 or COM2

The IO/AT is an I/O board for the IBM PC, PC/XT, PC/AT, PS/2 models 25 and 30, and fully compatible computers. It provides a 25-pin parallel port, which you can address as LPT1, LPT2, or a user-selectable port. It also provides a 9-pin serial port that you can address as COM1, COM2, or a user-selectable port. An NS16450 UART chip provides the interface to the serial port. An op-



tional 25-pin serial port is also available. You can access the additional serial port by connecting a ribbon-cable assembly to the board. If you install four of the boards, each with the optional serial port, in your PC, the PC will be able to communicate with as many as eight serial devices. The board has no switches or jumpers to set, so a particular configuration is completely software controlled. Once the address selections have been made, they are stored on the board in static RAM that's pow-

Now with zero wait-states at 20 MHz

# Race Card

The HK68/V2F is a high-performance VME microcomputer with race-bred 32-bit power for real-time applications.

High engine output and economical, dependable performance are just the start of the HK68/V2F's standard equipment:

- Up to 25MHz Motorola 68020 CPU
- Up to 4MB of on-board DRAM with parity
- 128K EPROM
- Serial Port
- Mailbox interrupt support
- VSB compatible memory expansion bus

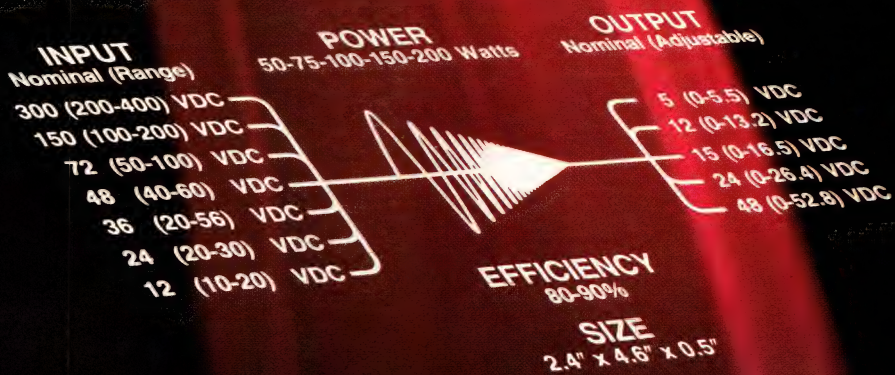
Optional racing equipment includes 68881 Floating Point Coprocessor and no wait-state DRAM.

# HEURIKON CORP.

Take Heurikon's HK68/V2F for a test-lap today. Call toll-free: 1-800-356-9602 (ext. 912).



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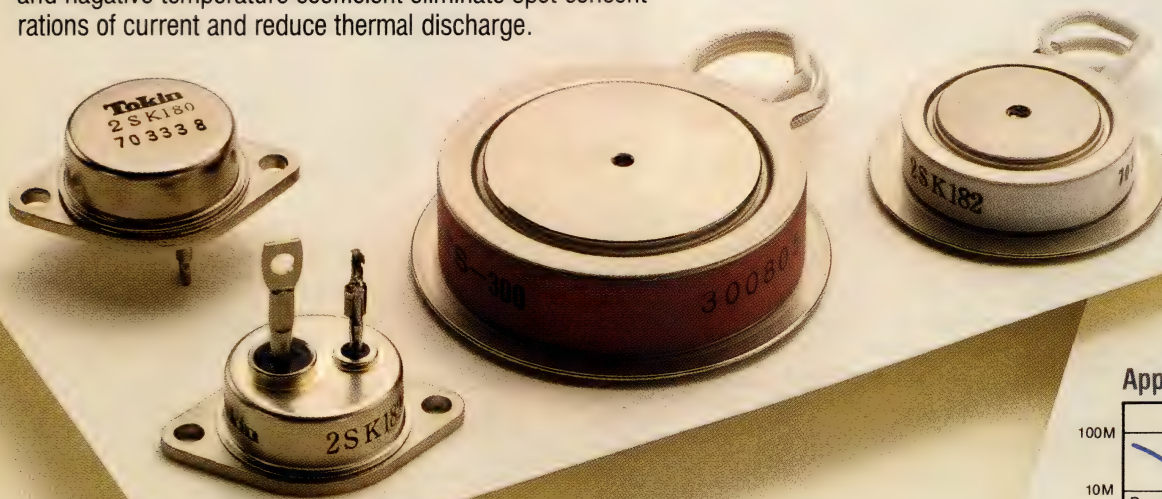
# Beyond FET: SIT, from Tokin.

Tokin introduces SIT (Static Induction Transistor), an all new high-power vertical field effect transistor featuring unsaturated current and low drain-to-source resistance.

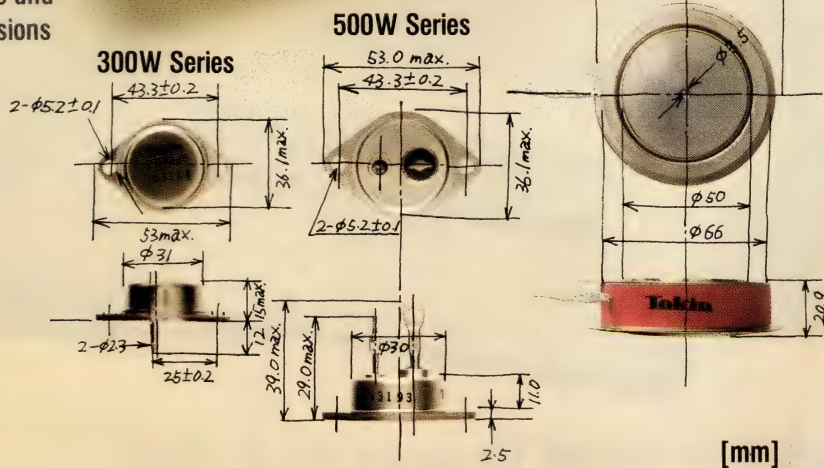
Tokin accomplished this by minimizing gate resistance and high frequency signal loss. And its heat-proof design and negative temperature coefficient eliminate spot concentrations of current and reduce thermal discharge.

This means SIT can be used for a wide range of practical high-frequency, high-power applications, from high-power ultrasonic devices to induction heaters, from power supplies for lasers to amplifiers and transmitters.

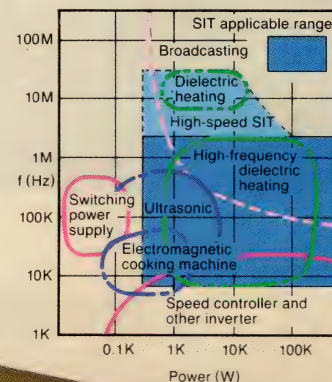
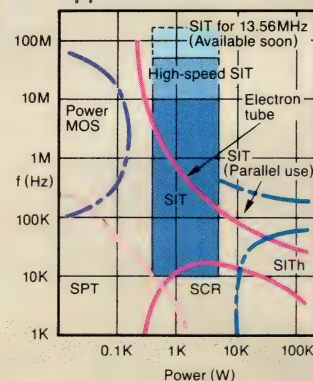
Put some punch in your performance. Call us now.



## Shapes and Dimensions



## Applications of SIT



## Electrical Characteristics (Ambient Temperature: 25°C)

Term	2SK180	2SK181	2SK182E	2SK183E	2SK183HE	2SK183VE	2SK182	2SK183	2SK183H	2SK183V	T5300	T5300H	T5300V
Storage Temperature	-50 ~ +150°C												
Gate to Source Voltage	70V												
Gate to Drain Voltage	600V	800V	600V	800V	1200V	1500V	600V	800V	1200V	1500V	600V	1200V	1500V
Drain Current	20A			60A			60A			200A			180A
Total Power Dissipation	300W			500W			1000W			3000W			
Insertion Gain	10*			12*			10*			12*			12*
Cutoff Frequency	10MHz*			10MHz*			10MHz*			7MHz			
Drain to Source ON Resistance	1.50 max.	20 max.	1.00 max.	1.50 max.	1.00 max.	1.50 max.	0.30 min.	0.50 max.					
Turn-On TIME	200ns*			250ns*			250ns*			350ns*			
Turn-Off TIME	250ns*			300ns*			300ns*			350ns*			

\* Nominal value.

CIRCLE NO 202

## Tokin

### Tokin Corporation

**Head Office**  
 Hazama Bldg., 5-8, Ni-chome, Kita-Aoyama,  
 Minato-ku, Tokyo 107, Japan  
 Tel: Tokyo (03) 402-6166 Fax: Tokyo (03) 497-9756  
 Telex: 02422695 TOKIN J

### Tokin America Inc.

2261 Fortune Drive, San Jose, California 95131, U.S.A.  
 Tel: 408-432-8020 Fax: 408-434-0375

### Chicago Branch

Presidents Plaza 1, Suite 200N, 8600 W. Bryn Mawr,  
 Chicago, IL 60631  
 Tel: 312-380-0030 Fax: 312-693-8334

### München Liaison Office

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You can reach our agents by phone: London 01-837 2701; Paris 1-45 34 75 35; Milan (0331) 678-058;  
 Munich (089) 5164-0; Seoul (02) 777-5767; Taipei (02) 7311425; Hong Kong 3-315769; Singapore 747-8668



## COMPUTERS & PERIPHERALS

ered by a lithium battery. The boards measure 4.3×4.2 in. and are FCC Class B certified. IO/AT board with one serial and one parallel port, \$119; with two serial and one parallel ports, \$139.

**Boca Research Inc.**, 6401 Congress Ave, Boca Raton, FL 33487. Phone (305) 997-6227. TLX 990135.  
Circle No 417

## HANDHELD TERMINAL

- Contains DTMF communications circuit
- Features 2-line, 32-character display

The MultiPortable pocket-size data terminal uses an 8-bit  $\mu$ P that features communication circuits for DTMF (dual-tone multifrequency) and tone transmission. The  $\mu$ P also provides audio-tone monitoring and pulse-width timing for tone detection. The terminal has 64k bytes of internal memory, an 8-bit parallel port, an RS-232C port, and three I/O and control ports. The package includes a 66-character qwerty keyboard and a 2-line, 32-character liquid-crystal display. An optional 1200-bps modem transfers data via two RJ-11 telephone-jack interfaces. When functioning as a voice terminal and "smart" telephone, the unit stores names, addresses, and numbers in a directory that enables it to perform automatic dialing. One edge of the terminal contains a Memocard access port. This port can transfer and accept data from a credit-card-size memory card containing an EEPROM. The unit measures 6½×3¾×1¼ in. and weighs about 12 oz. Terminal with optional modem, \$650; 2k-byte Memocard, \$79; 8k-byte Memocard, \$139.

**Multimil Inc.**, 670 International Parkway, Suite 190, Richardson, TX 75081. Phone (214) 644-7724. TLX 286258.

Circle No 418

# BERTAN

## The New Era in High Voltage

## Series 225 IEEE-488 Programmable High Voltage Power Supply



Integrated IEEE488 Interface  
Programmable Operating Modes  
0.001% Regulation  
0.1% Setting & Monitor Accuracy  
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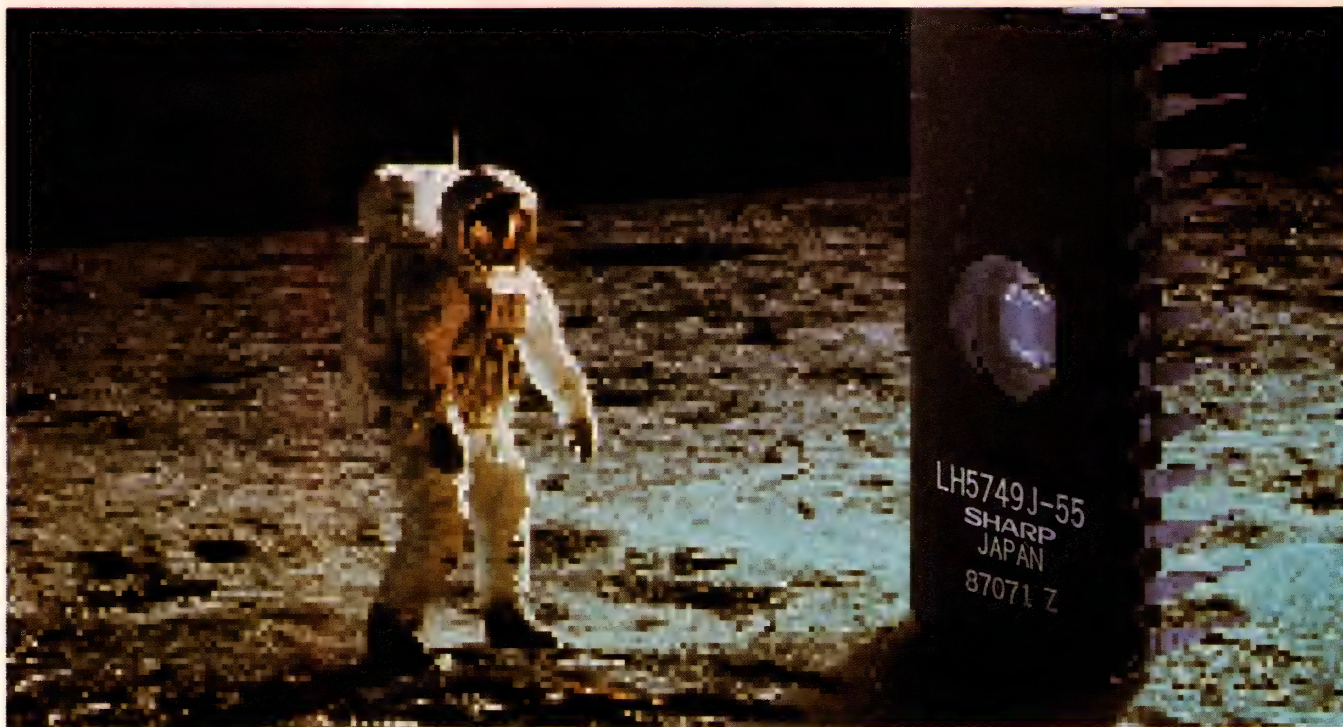
CIRCLE NO 65

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	LH5762	64K	8K x 8	70ns	NOW
EPROM/OTP	LH5763J	64K	8K x 8	70/90ns	NOW
	LH5763	64K	8K x 8	90ns	NOW
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## CAE & SOFTWARE DEVELOPMENT TOOLS



### DESIGN KIT

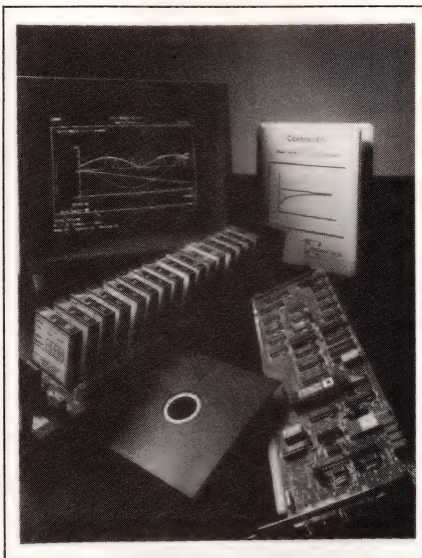
- Lets you evaluate memory-management performance
- Includes graphics-symbol libraries

Memory-management design kit SN74MMDK01 consists of technical data, application information, libraries of schematic-capture graphics symbols, and samples of the vendor's memory-management ICs. The documentation includes data sheets for each of the sample devices and related products, and the vendor's *Memory-Management Applications Handbook*. You can use the symbol libraries, which are from Logic Automation and FutureNet, on the FutureNet and Mentor Graphics CAE systems; Logic Automation also supplies behavioral-simulation models for the memory-management devices in the kit. These devices include dynamic-RAM controllers, cache-address comparators, error-detection and -correction circuits, and memory drivers. You can use the kit either to shorten the design time of a memory system or to evaluate performance improvements gained by using the vendor's devices. \$149.

**Texas Instruments Inc.**, Semicon-

ductor Group (SC-780), Box 809066, Dallas, TX 75380. Phone (800) 232-3200, ext 700.

Circle No 373



### CONTROL SOFTWARE

- Monitors as many as 128 analog inputs
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◀ 8 x 8 bit Multiplier ▶  
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and you can change system parameters (such as alarm limits) while collecting data. The typical scanning rate on an IBM PC/AT is 64 channels/sec. \$500.

Analog Devices Literature Center, 70 Shawmut Rd, Canton, MA 02021. Phone (617) 461-3359. TWX (710) 394-6577.

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## IC-SIMULATION MODEL

- Lets you simulate a board using BIT components
- Works with popular CAE programs

You can order SmartModel logic-simulation models for four components manufactured by BIT (Bipolar Integrated Technology Inc): the

B3018A/B2018 16×16-bit fixed-point multiplier; the B3011/B2011 multiplier-accumulator; the B3210/B2210 5-port register file; and the B3110/B2110 floating-point multiplier. The vendor will soon offer a model for BIT's B3120/B2120 floating-point ALU. You can use the models with most popular CAE programs and with a variety of workstations. Workstation licenses cost \$950 each for the B3011/B2011, B3018/B2018, and B3210/B2210, and \$1800 each for the B3110/B2110 and B3120/B2120.

Logic Automation Inc, 19500 NW Gibbs Dr, Beaverton, OR 97006. Phone (503) 690-6900.

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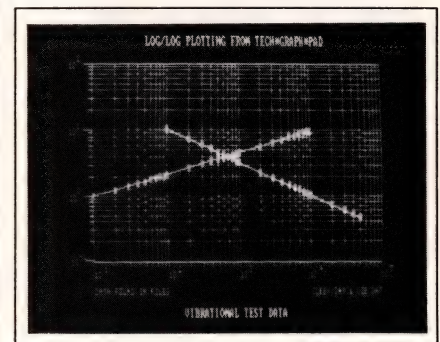


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- Works with files and data-acquisition software

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CIRCLE NO 230



have complete control over the scaling and the placement of axes, labels, and notations. For hard copy, you can use a wide variety of plotters and dot-matrix printers. To run the program, you'll need an IBM PC, PC/XT, PC/AT, or a compatible computer that's equipped with at least 512k bytes of RAM and runs MS-DOS version 2.0 or later. \$275.

**Binary Engineering**, 100 Fifth Ave, Waltham, MA 02154. Phone (617) 890-1812.

Circle No 376

## WAVE-SOLDER CONTROL

- Allows off-line programming of wave-soldering machines
- Lets you write parameters to EPROM

The ElectroSave software package—which runs on the IBM PC, PC/XT, PC/AT, and fully compati-



ble computers—allows you to perform off-line programming of the vendor's  $\mu$ P-controlled Econopak II wave-soldering system. By following the program's menu selections and prompts, you can create a file containing a complete set of operating parameters for the production run of a given board type; the parameters include preheat temperature, flux density, solder temperature, wave height, and conveyor

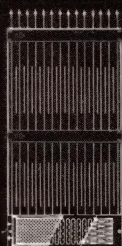
speed. You can later recall the parameters for display on the screen or on the system printer, and you can change any or all parameters. When you are satisfied with the values, you can download the file, via an RS-232C link, to the Econopak II machine for execution of a soldering run. You can also upload parameters stored in the machine for archival storage in an EPROM. To run the program, you'll need an IBM PC or compatible computer that's equipped with the IBM Monochrome Display and Printer Adapter (or equivalent) and an Epson-compatible dot-matrix printer. The package comes with a ribbon cable to connect the Econopak machine to the PC's serial port; it also comes with EPROM chips, and a program disk with a backup copy. \$1195.

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## SOFTWARE TOOL

- *Program development for  $\mu$ Cs without in-circuit emulation*
- *Runs on an IBM PC*

This version of the chipForth software-development environment allows you to write and debug software for Intel's 8051/8031 family of microcontrollers without using an in-circuit emulator. Instead, chipForth provides interactive program development, using only the on-chip RAM of the  $\mu$ C and a ROM emulator. You can write programs that use only the on-chip RAM and ROM of the  $\mu$ C or programs that use the 8051's 64k bytes of external data and program space. You can also implement systems with overlapping data and program space. The development environment uses the Forth programming language combined with an editor, an assembler, and a compiler. This development software runs on an IBM PC, PC/XT, PC/AT, or a compatible computer linked to the target system via a serial port. The Forth multitasking kernel that is supplied uses as few as 40 bytes/task. It imposes no overhead on the  $\mu$ C's interrupt handling and does not affect its bit-handling capabilities. £1800.

**Computer Solutions Ltd**, Canada Rd, Byfleet, Surrey KT14 7HQ, UK. Phone (09323) 52744. TLX 946240 (Request ref 19012265).

**Circle No 378**

## TERMINAL EMULATOR

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- *Includes a communications card for the PC*

The PC70 hardware/software package allows one or two IBM PC, PC/XT, PC/AT, or compatible computers to operate as IBM-3270 BSC (binary synchronous communications) workstations. The package includes a full-length add-in card that you can configure as the PC's COM1

or COM2 port, and terminal-control software that performs the 3270 emulation. You can link the card both to the host and to another PC, enabling each to operate as a 3270 workstation. Both workstations can use their own printers. If you don't use the second workstation facility, you can employ the second port on the card to drive a line printer di-

rectly. You can link the package to the host system via a null modem or via a modem/line driver connected to a leased line. £850.

**Sipher Designs (Electronics) Ltd**, Unit 14, St George's Industrial Estate, White Lion Rd, Amersham, Bucks HP7 9JQ, UK. Phone (02404) 5335. TLX 83293.

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Compact Software Inc, 483 McLean Blvd, Paterson, NJ 07504. Phone (201) 881-1200.

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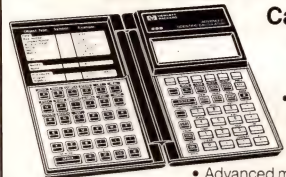
### ASIC EXPERT SYSTEM

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- Builds knowledge base for optimizing ASIC designs

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- Time value of money; percent change
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specific component-library symbols; then you draw the consequent circuit, a less obvious but more efficient circuit that provides the same functionality. You also define the port, mapping between the two circuits. The knowledge compiler then verifies that the two circuits are logically identical and determines the speed and area factors for each of the circuits. If the knowledge you are adding is already in the knowledge base, the program so informs you; otherwise it compiles the

knowledge into the knowledge base. The system runs on a Mentor Graphics (Beaverton, OR) workstation. \$49,500.

**Trimeter Technologies Corp.**, 200 Hightower Blvd, Suite 100, Pittsburgh, PA 15205. Phone (412) 787-8630. TWX 510-601-3773.

**Circle No 381**

## IC DESIGN TOOL

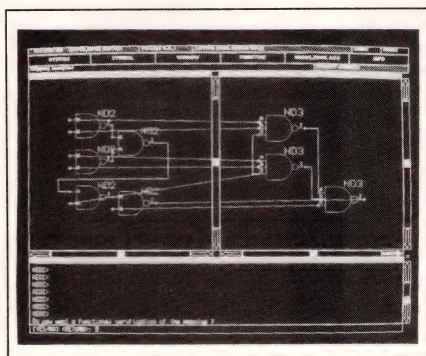
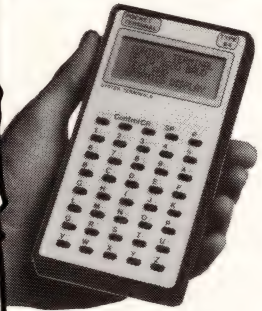
- Provides a common user interface for design tools
- Allows foundry-independent IC design

The Spirit IC design environment provides you with a stable user interface through which you can access a variety of proprietary or commercial IC design tools. The user interface remains the same even if you add to or change the set of design tools, so you don't need to learn a new user interface for each

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**Integrated Circuit Design BV**, Box 3132, 7500 DC Enschede, The Netherlands. Phone (053) 306455. TLX 72280.

**Circle No 382**


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The range starts with simple ASCII keyboards and goes right on up to sophisticated programmable, battery-powered terminals. The units on the left are just a few examples of what we can offer.

For OEMs we have a special engineering service, enabling us to customise any of our standard units to specific requirements.

If you can't see exactly what you want, then give us a call.

- Applications include:
- PRINTING
  - AEROSPACE
  - TELECOMMUNICATIONS
  - PROCESS CONTROL
  - ATE

1640 Fifth Street,  
Santa Monica, CA 90401  
Tel: (213) 395-4774.  
Telex: 65-2337.  
Facsimile: (213) 393-6040

301 Daniel Webster Highway,  
Merrimack, NH 03054  
Tel: (603) 429-2566





# WAIT

## THE WAIT FOR ABSOLUTE FLEXIBILITY IN HIGH POWER IS OVER

### WAIT UNTIL YOU READ THIS

You can have up to 5 outputs with unlimited flexibility of output voltage and current combinations with acdc electronics' NEW 1600W power supply. That's UNLIMITED combinations! Check the chart below.

### DON'T WAIT... SEE—THE SMALLEST 1600W PACKAGE

acdc electronics has packaged 1600 W into a 5" x 8" x 13" profile. That makes acdc's JFM Series the SMALLEST 1600W multi output switch mode power supply available. Anywhere!

### THE WAIT FOR INDEPENDENT AUXILIARY OUTPUTS IS OVER

Each JFM auxiliary output is an independent, switch mode power supply which eliminates all cross regulation problems. Additional standard features—never before offered on a high power multi—include: remote sense, margining and inhibit... on each auxiliary output.

And, to troubleshoot your system, independent LED's indicate output out-of-tolerance and identify the faulty output.

**WAIT NOT** Don't wait for the power supply you need. Any output voltage combination listed in the model selection chart will be delivered in two weeks!

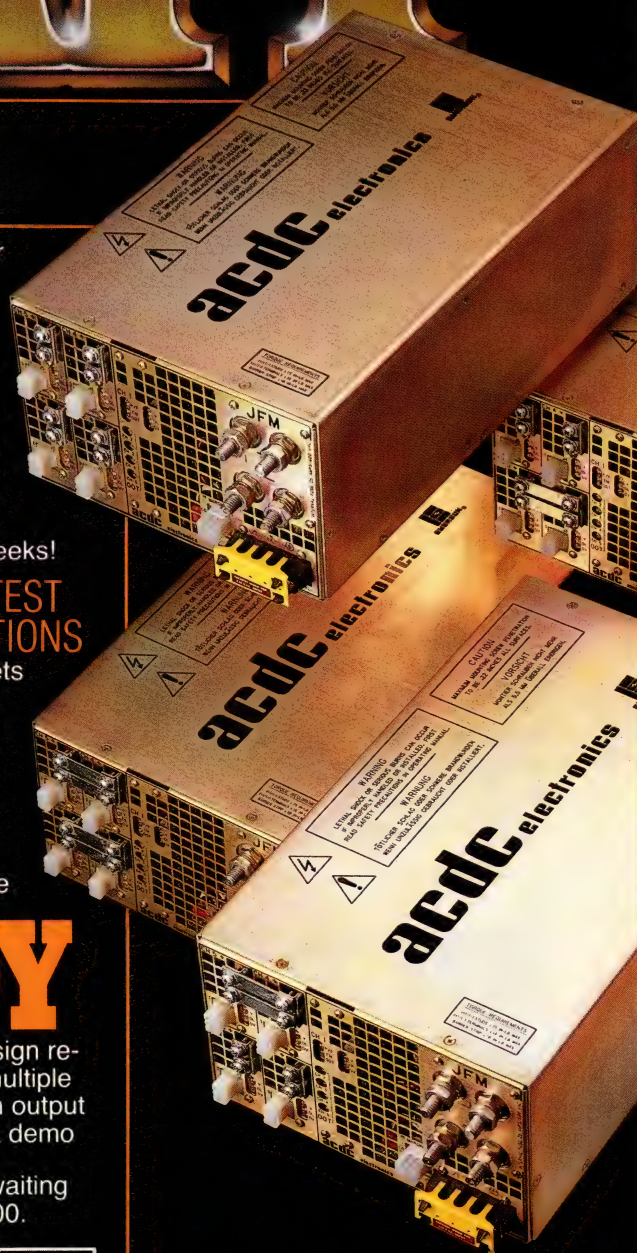
### WAIT UNTIL YOU TEST THESE SPECIFICATIONS

- Internal EMI Filter meets FCC & VDE Class A
- All outputs are floating
- No minimum load required on any output
- Single-wire paralleling (main output)
- Current monitor
- 30 Ms holdover storage

## READY

Are you working on a design requiring high power and multiple outputs? With flexibility in output Voltages? Do you need a demo now?

The solution is ready & waiting for your call. 619 439-4200.



#### 1600W MULTI

MAIN OUT	CH2	CH3	CH4	CH5
5V/200A	TABLE A or B	TABLE A or B		
5V/200A	TABLE A or B	TABLE B	TABLE A or B	
5V/200A	TABLE B	TABLE B	TABLE B	TABLE B

1500w	800w	500w	300w	175w	70w	15w
1600w	1000w	750w	400w	220w	135w	40w

#### TABLE A AUX's

5V/60A  
12V/30A  
15V/24A  
24V/15A

#### TABLE B AUX's

5V/30A  
12V/15A  
15V/12A  
24V/7.5A

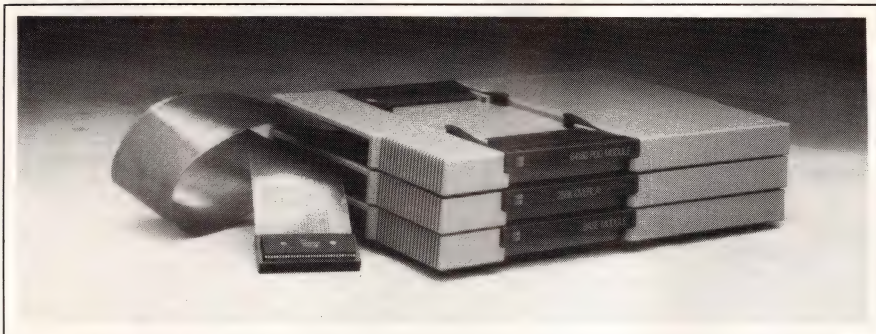
**acdc**  
electronics

401 Jones Road, Oceanside, CA 92054.  
TEL: 619/757-1880. TLX: 350227. FAX: 619/439-4243



# NEW PRODUCTS

## TEST & MEASUREMENT INSTRUMENTS



### Z80/64180 EMULATOR

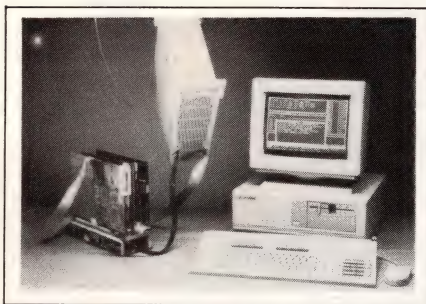
- Emulates Z80H at full speed with no wait states
- Provides 8k×48-bit words of high-speed trace memory

The EL 800 in-circuit emulator performs zero-wait-state emulation of the Z80H  $\mu$ P at 8 MHz and the HD64180 at 6 MHz without preempting any interrupts. To minimize propagation delays, the device uses a hybrid circuit rather than the more common passive connection. The emulator plugs into the target  $\mu$ P socket and drives the 16-in. cable back to the emulator. The emulator itself is packaged as a group of 8.5×11×0.85-in. modules that stack on top of one another and snap together to make electrical as well

as mechanical connections. A single power supply energizes all of the units. You need to purchase only one module; you add features—for example, 64k to 256k bytes of overlay memory with optional battery back-up—by adding modules. Your personal computer (running MS-DOS 3.0 or higher and having 640k bytes of RAM) acts as host; you connect the emulator to either the COM1 or COM2 port. You can display the 8k×48-bit words of trace memory in several ways: for example, you can restrict the display of write instructions to those that write to data space. \$4850.

**Applied Microsystems Corp.**, Box 97002, Redmond, WA 98073. Phone (206) 882-2000. TLX 185196.

Circle No 420



### IN-CIRCUIT EMULATOR

- Emulates Z80, 68000, 80186, and 80188  $\mu$ Ps
- Optional state and timing analyzer

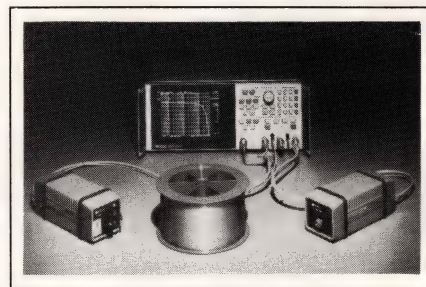
Hosted by an ASCII terminal or a computer, the HP 64700 Series em-

ulator/analyzer performs transparent, real-time emulation and analysis of systems based on the Z80, 68000, 80186, and 80188  $\mu$ Ps. Optional versions can also perform 16-channel logic-state analysis at 25 MHz and timing analysis at 100 MHz. You can trigger the logic analyzer without breaking the emulated processor's program execution. All units include an emulation analyzer with which you can trace the code flow. Using the analyzer, you can prestore and time-tag instructions and qualify the trace specifications with sequences of as many as eight system states. The hardware includes a code-coverage

analyzer; it provides a history of the memory addresses that the  $\mu$ P reads from or writes to during program execution. 8-bit  $\mu$ P without logic analyzer, \$8900 to \$12,500; 16-bit  $\mu$ P, \$11,300 to \$14,650.

**Hewlett-Packard Co.**, 1820 Embarcadero Rd, Palo Alto, CA 94303. Phone local office.

Circle No 421



### PHOTONIC ANALYZER

- Includes light source and receiver
- Handles modulation frequencies as high as 3 GHz

The HP 8702A photonic analyzer system is a design and analysis tool for high-bandwidth (that is, high-bit-rate) optoelectronic components. Such components include transmitters, receivers, couplers, and fibers used in long-haul fiber-optic communications systems. The analyzer extends microwave-network analysis techniques (and, optionally, time-domain analysis techniques) to equipment that modulates and transmits light waves. The system, which can include both a lightwave source and a lightwave receiver, measures modulation bandwidth, responsivity, modulation and detection sensitivity, dynamic range, linearity, attenuation, and delay. A synthesized 300-kHz to 3-GHz RF source provides the modulating signals, and a calibrated 3-channel receiver measures the magnitude and phase of demodulated signals. The time-domain option enables the ana-

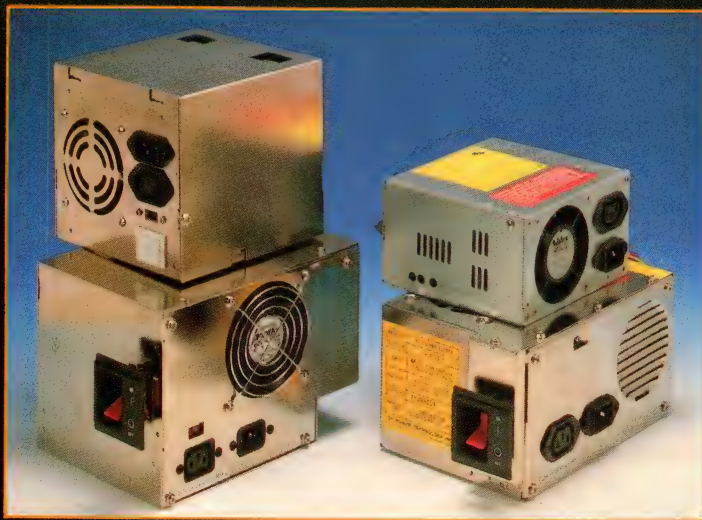


# Switch with Liton

## 20-1,000W-Meets FCC, UL, CSA, TUV and VDE standards



Taiwan Liton Electronic Co., Ltd. produces a greater range of high-performance switching power supplies than most any other manufacturer anywhere: 20-1,000W. By customizing cost-saving standard models with an alternative component or two, available SPS configurations run into the thousands. Design and production fully meets FCC class "B", UL, CSA TUV and VDE standards. Applications include PCs and workstations, telecommunications equipment, as well as OA equipment like facsimile machines, copiers and printers. PC models are electrically as



well as physically IBM PC/AT, PC/XT compatible and are full-power rated and wired for hard-disk or tape drives, as well as other peripherals. We've built our reputation with top-quality components. With gigantic facilities and modern equipment, we design and manufacture computer and communications products which meet the highest international quality control and performance standards. Our R&D customizes a standard model or generates a 100% original design in a lead time worth switching for!

**Taiwan Liton Electronic Co., Ltd.**

12th Fl., 25 Tunhwa S. Rd., Taipei, Taiwan, ROC

Tel: (02) 771-4321/8 Fax: 886-2-751-1962 Tlx: 24514/20211 TWLITON

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CIRCLE NO 227



lyzer to make pulse-dispersion measurements. Analyzer, \$28,000; time-domain option, \$4800; single-mode or multimode light source, \$12,700; lightwave receiver, \$5000. Delivery, eight weeks ARO.

**Hewlett-Packard Co.**, 1820 Embarcadero Rd, Palo Alto, CA 94303. Phone local office.

**Circle No 422**

## Z280 EMULATOR

- Supports 16M-byte address space
- Handles the  $\mu$ P's 8- and 16-bit buses

The Z280 IceAlyzer is an in-circuit emulator for Zilog's Z280  $\mu$ P. With the addition of an RS-232C-interfaced ASCII terminal, the system supports the Z280's 10-MHz maximum clock rate, 16M-byte address space, memory manager, extended I/O addressing, and both the 8- and

16-bit buses. You can set 32,000 hardware breakpoints so that they take effect individually or in regions and on read, write, or fetch cycles. To debug ROM-based systems, you can overlay 256k bytes of RAM anywhere in the Z280's address space. The unit has built-in tests for common target-system hardware faults. It also performs software-performance analysis. \$7995.

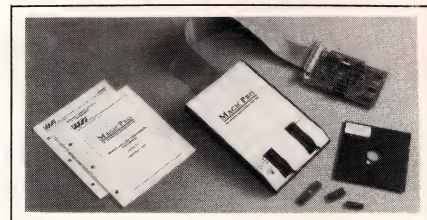
**Softaid Inc.**, 8930 Rte 108, Columbia, MD 21045. Phone (800) 433-8812; in MD, (301) 964-8455.

**Circle No 423**

## PROGRAMMER

- Programs small lots during development
- Supports vendor's programmable-device line

The MagicPro memory and logic programmer runs on a PC bus-based personal computer and is



suited to programming small quantities of the vendor's devices. It provides 20 lines that address 1M bytes and has 16-bit-wide I/O. A cable connects the PC Bus short card to a pair of ZIF (zero insertion force) sockets that, without adapters, accommodate DIP devices having 24, 28, 32, and 40 pins in rows on 0.3- and 0.6-in. centers. Socket adapters enable the programmer to handle LCC and PGA (pin-grid-array) packages. The product's support software comes on a 5¼-in. disk. \$995.

**Waferscale Integration Inc.**, 47280 Kato Rd, Fremont, CA 94538. Phone (415) 656-5400. TLX 289255.

**Circle No 424**

# the low profile answer to the high power question . . .

The next time you ask yourself how to get all that power into such a small space, think of Intronics.

Introducing our new 100 Watt triple output, low profile DC/DC converter.

The KZ 400 Series does the job of three single output converters in a much smaller area—saving you valuable board space. It costs significantly less than individual converters and saves time and money on installation and inspection.

Designed primarily for the telecommunications, computer and instrumentation markets, the KZ 400 is metal encased with six-sided shielding and comes with a number of standard features. With 20 standard single and triple output models to choose from, it boasts a wide input range of 20-60 VDC and 36-72 VDC.



The KZ 400 delivers an impressive 80% typical efficiency and has a fixed switching frequency of 200 KHz. Line/load regulation specifications are  $\pm 1\%$  main channel and  $\pm 5\%$  auxiliaries. The unit is available in PC board and side mount models.

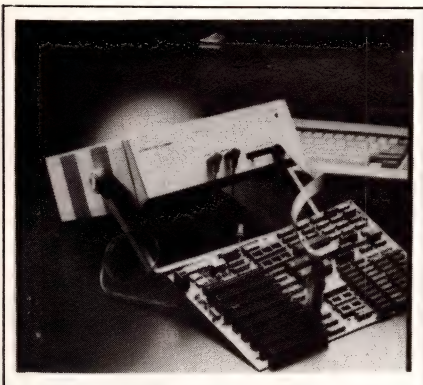
Get all the power you need at a lower cost—while increasing valuable board space. And at Intronics, you also get dependable service and product support. Call Intronics today at (617) 964-4000 about the new 100 Watt KZ 400 triple output DC/DC converter—the answer to your high power needs.

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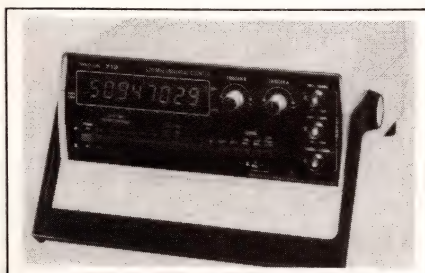
## PC-BOARD TESTER

- Locates defective components
- Learns and stores signatures of device and board pins

The portable Board Wizard locates defective components on pc boards. It can learn and store characteristic signatures at each pin of known-good boards and devices such as ASICs and PLDs. The tester compares the stored signatures against signatures measured on the board under test. The unit can also conduct comparisons by referring to a library of signatures for 74-series TTL devices. \$3495.

**Suan Technologies (USA) Inc.**, 18437 Saticoy St, Suite 8, Reseda, CA 91335. Phone (818) 996-1386.

Circle No 425



## COUNTERS

- Count at 200- and 520-MHz rates
- Display uses eight 0.56-in.-high LEDs

The 712 is a 200-MHz counter; the 713 is virtually identical, but it handles frequencies to 520 MHz. The 712 has two channels, the 713 three. Besides indicating a signal's frequency, both units totalize from 10

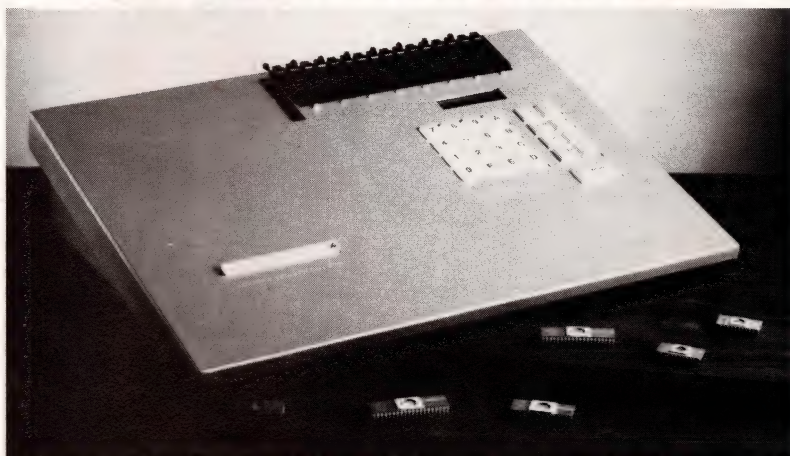
Hz to 10 MHz, and measure period and frequency ratios from 10 Hz to 2.5 MHz and time intervals from 0.5  $\mu$ sec to 0.2 sec. Their time bases spec  $\pm 5$  ppm/yr aging and  $\pm 10$  ppm temperature stability from 0 to 50°C. The instruments include 1-MHz lowpass filters with selectable attenuation; in the self-check mode, each instrument displays the

frequency of its 10-MHz internal timebase. The counters' 8-digit displays use 0.56-in.-high LEDs and provide overflow, gate, microsecond, and kilohertz indicators. Model 712, \$525; Model 713, \$675.

**Simpson Electric Co.**, 853 Dundee Ave, Elgin, IL 60120. Phone (312) 697-2260. TLX 722416.

Circle No 426

## BYTEK's NEW 135 MULTIPROGRAMMER™ OFFERS 18/12 PROTECTION PLAN



### THREE PROGRAMMERS IN ONE.

With the addition of the 135 MultiProgrammer™ BYTEK has provided a true Universal Programming Site. The 135 is a SET EPROM Programmer, a GANG EPROM Duplicator, and a UNIVERSAL DEVICE Programmer, designed for Engineering Development, Production and Field Service Environments.

**BYTEK's new 135 MultiProgrammer™** is a High Performance Instrument setting new standards for Universal Device Support and Flexibility at affordable prices.

**VERSATILE:** With standard 256K BYTE of RAM, expandable to 2 MegaByte, the 135 supports more devices than any other production programmer on the market today. The 135 provides EPROM programming capabilities of virtually any 24-, 28-, and 32-Pin EPROM and EEPROM from 16K to MegaBit Devices. The 135 can Program SETS of Devices, 16- and 32-Bit Wide. As a GANG EPROM Duplicator, it copies up to eight (8) devices from RAM, with options for 16 Devices.

**COMPATIBLE:** The 135 offers Terminal and Computer Remote control, Data I/O\* compatible+.

\* Data I/O is a Registered Trademark of Data I/O Corporation.  
+Some limitations may apply.

**FLEXIBLE:** The 135 can easily be expanded to program 40-Pin EPROMs, Bipolar PROMs, Logic Array Devices, EPROM Emulation, and 40 Pin Micro Devices.

**18/12 PROTECTION PLAN:** BYTEK offers High Performance, unsurpassed quality, and product reliability. BYTEK is the first to offer a full EIGHTEEN MONTH WARRANTY, and TWELVE MONTH FREE Device Support Updates.

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### BYTEK International

511 11th Ave., So. Minneapolis, MN 55415  
Tel: (612) 375-9517 FAX: (612) 375-9460  
Telex: 4998369 BYTEK



## VHSIC VERIFIER

- Operates at 100 MHz
- Accommodates 448 channels

The Logic Master XL 100 prototype verification system supports 100-MHz clock and data rates. The vendor claims that this speed exceeds the test requirements of VHSIC-Phase-II parts and that the sys-

tem's 100-psec edge placement, 125-psec frequency resolution, and 448-channel capability are appropriate for at-speed verification of ECL and GaAs ASICs. The system comes with an automatic tool for speeding fixture fabrication, reducing wiring errors, and maintaining a 50 $\Omega$  device environment. The system, which can contain 16 to 224 bidirec-

tional channels or 32 to 448 split pattern-generation and data-acquisition channels, provides 12 timing sets, each consisting of two edges; you can assign any timing set to any pin. With 128 bidirectional channels, \$250,000.

**Integrated Measurement Systems**, 9525 SW Gemini Dr, Beaverton, OR 97005. Phone (503) 626-7117.

Circle No 427

## Your best defense against EMI military or commercial

To start, get Amco's EMI enclosure catalogs — #204 for military and heavy duty, #650 for FCC and commercial. They're FREE and so is the call.

Then, when you're ready to start your project, call Amco with your requirements for a FREE INITIAL CONSULTATION and cost estimate.

Why Amco? Because there's no room for compromise when you have to meet rigid specifications like **MIL 285, FCC requirements or Tempest program**. Amco has the EMI experience and know-how that goes back to 1962, when we developed the first modular EMI system for NASA. Amco has led the industry in EMI shielded consoles and cabinets ever since.

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In Illinois, Call (312) 671-6670

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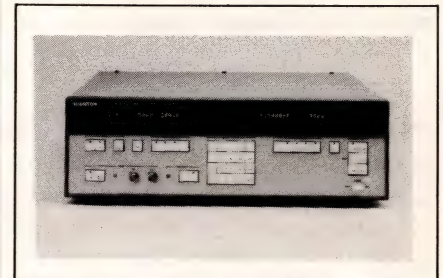
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In Illinois call (312) 671-6670  
FAX: 312-671-9496



## AUTOMATED BRIDGE

- Measures series and parallel capacitance and loss
- Shows loss as Q, resistance, conductance, or dissipation

The 7600  $\mu$ P-controlled automated bridge makes 3-terminal measurements of series and parallel capacitance and loss. The bridge operates at 1 MHz, and it lets you add programmable external bias voltages of  $\pm 100$ V or  $\pm 200$ V. It makes as many as 70 readings/sec and can display losses as resistance, conductance, dissipation, or Q. The bridge can display the actual measured capacitance or it can display the difference between the measured value and a user-entered nominal value either as a percentage of the nominal or as a difference. The bridge can automatically select full-scale capacitance ranges of 1.9900 pF through 1990.0 pF, or you can choose the range manually. When making remote measurements, the bridge automatically compensates for capacitance of cables of selectable length. The instrument features a real-time clock for time and date stamping of hard-copy records, and three interfaces: Centronics parallel, RS-232C



## TEST & MEASUREMENT INSTRUMENTS

serial, and IEEE-488 high-speed parallel. \$12,500. Delivery, 16 weeks ARO.

**Boonton Electronics Corp**, 791 Rte 10, Randolph, NJ 07869. Phone (201) 584-1077.

Circle No 428

### LINEAR IC TESTER

- Performs go/no-go tests and measures parameters
- Tests more than 150 op amps and voltage comparators

The Model 750  $\mu$ P-based benchtop linear IC tester tests more than 150 types of single, dual, triple, and quad op amps and voltage comparators. It performs both go/no-go and parametric tests on such devices. When performing go/no-go tests on an op amp, the tester first verifies that the device is closed-loop stable. The tester then ascertains whether the device's output can swing to at

least 75% of the supply voltage. Next, it measures the device's gain-bandwidth product and compares this measurement against a predetermined limit. When operating in the parametric-measurement mode, the tester can perform 10 types of tests and provide quantitative data; it can run the tests in sequence and can hold the data on its display until you issue a command for it to proceed to the next test. \$2495.

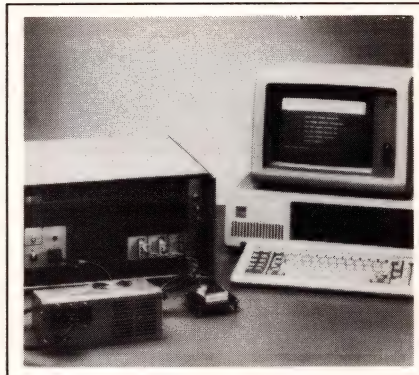
**Information Scan Technology Inc**, 487 Gianni St, Santa Clara, CA 95054. Phone (408) 988-1908.

Circle No 429

### SUPPLY TESTER

- Hosted by MS-DOS-based PC
- Has Basic-language software that supports 14 tests

The Model 701 power-supply tester can reside on a desktop. It utilizes an MS-DOS-based IBM PC-compat-



ible computer as a controller. The software supports 14 tests, which include current-limit and voltage adjustments, a p-p noise test, combined line- and load-regulation measurements, and, for multiple-output supplies, cross-regulation measurements. The programming language is Microsoft Basic. Including computer, \$11,950.

**Condor Inc**, 2311 Statham Parkway, Oxnard, CA 93033. Phone (805) 486-4565.

Circle No 430

**5 nsec rise & fall times from the Crystalmaster**

**HIGH SPEED, AUTO INSERTABLE, CMOS**

# PLASTIC DIP OSCILLATOR!

The new EPSON SG-51 Series plastic DIP CMOS crystal oscillator has typical 5 nsec rise and fall times. And it occupies about half the board space of the metal can oscillator it replaces. Both versions of the SG-51, 4-pin and 14-pin, are auto insertable using standard DIP equipment, and the 4-pin fits the same hole pattern as metal can types. With tri-state output, low power consumption, high speed and now 4-pin or 14-pin plastic DIP... the Crystalmaster is first again!

**SPECIFICATIONS**

**CMOS Crystal Oscillator SG-51 Series**

Input Voltage: 5V  $\pm$  0.5V

Access Time: 8 nsec MAX, 5 nsec TYP

Frequency Stability: C =  $\pm$ 100 ppm

Duty: 40/60 to 60/40% at 1/2V<sub>DD</sub> or 1.4V level

Current Consumption: 18mA MAX, 10 mA TYP at 12 MHz

Output Load: 10 TTL gates

**OUTPUT FREQUENCIES**

20.0000 MHz	12.0000 MHz	6.1440 MHz	3.0720 MHz
19.6608 MHz	10.0000 MHz	6.0000 MHz	2.5000 MHz
18.4320 MHz	9.8304 MHz	5.0000 MHz	2.4576 MHz
16.0000 MHz	9.2160 MHz	4.9152 MHz	
12.2880 MHz	8.0000 MHz	4.0000 MHz	

**EPSON**

**EPSON AMERICA, INC.**

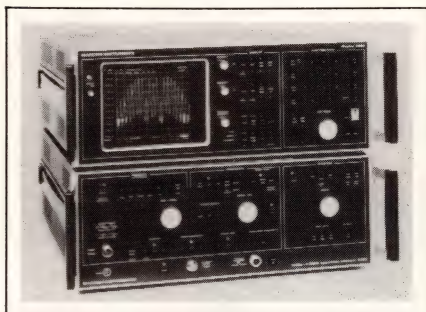
OEM Division

Component Sales Department

3415 Kashiwa St., Torrance, CA 90505

**Telephone (213) 534-4500 • TELEX 664277 • FAX (213) 539-6423**





## SPECTRUM ANALYZER

- Covers 100 Hz to 4.2 GHz
- Can resolve 3-Hz bandwidth

The 2383 spectrum analyzer covers the frequency range from 100 Hz to 4.2 GHz and can display a full-bandwidth sweep on a single screen. Its minimum resolution bandwidth is 3 Hz and its high-level accuracy is  $\pm 1.5$  dB with any control settings and at any specified operating temperature, even at 4.2 GHz. Its built-in tracking generator eliminates frequency-drift-induced impairment of swept-frequency synchronous meas-

urements. The instrument's intermodulation is better than  $-90$  dBc, and its residual responses are below  $-110$  dBm. An optional active probe permits you to take high-level measurements with minimal loading at frequencies as high as 1.25 GHz. The IEEE-488 interface permits a high-speed dump of the screen display to a host controller. \$41,950. Delivery, 60 days ARO.

**Marconi Instruments**, 3 Pearl Ct., Allendale, NJ 07401. Phone (201) 934-9050.

Circle No 431

## PLD PROGRAMMER

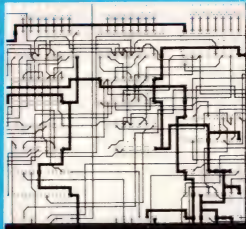
- Operates with an MS-DOS-computer host
- Programs 20- and 24-pin devices

The Avpal PLD programmer accepts JEDEC files created by CUPL and other PLD-programming languages. It permits you to load files directly from disk into a

buffer, edit the files, check PLDs to make sure they are blank, program PLDs from the buffer, read a chip into the buffer, and save the buffer contents to disk. The programmer also lets you read the status of a PLD's security fuse; blow the fuse to prevent unauthorized copying of the device; and display, print, or modify the device's fuse map. The unit consists of a card, which plugs into IBM PCs and compatible machines, and a remote head, which contains a zero-insertion-force socket and connects to the card via a cable. The MS-DOS-based software is menu driven. The programmer handles 20- and 24-pin PLDs made by Monolithic Memories, National Semiconductor, and Texas Instruments. \$395.

**Avocet Systems Inc.**, Box 490, Rockport, ME 04856. Phone (800) 448-8500; in ME, (207) 236-9055. TLX 467210.

Circle No 432



# CADDy's

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CIRCLE NO 81

## Series 10, 12, 14 & 16 Connector Cutout Covers



**F**or "D" Subminiature Cutouts; for Micro-Ribbon and Super-Ribbon Cutouts; for BNC, TNC, SMC and N Series Cutouts; and for Flange Mount Cutouts.

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**(213) 698 - 7793**

CIRCLE NO 82



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EDN provides accurate, detailed, and useful information about new technologies, products, and design techniques.

EDN covers new and developing technologies to inform its readers of practical design matters that will be of concern to them at once or in the near future.

EDN covers new products

- that are immediately or imminently available for purchase
- that have technical data specified in enough detail to permit practical application
- for which accurate price information is available.

EDN provides specific "how to" design information that our readers can use immediately. From time to time, EDN's technical editors undertake special "hands-on" projects that demonstrate our commitment to readers' needs for useful information.

EDN is written by engineers for engineers.

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EDN February 18, 1988

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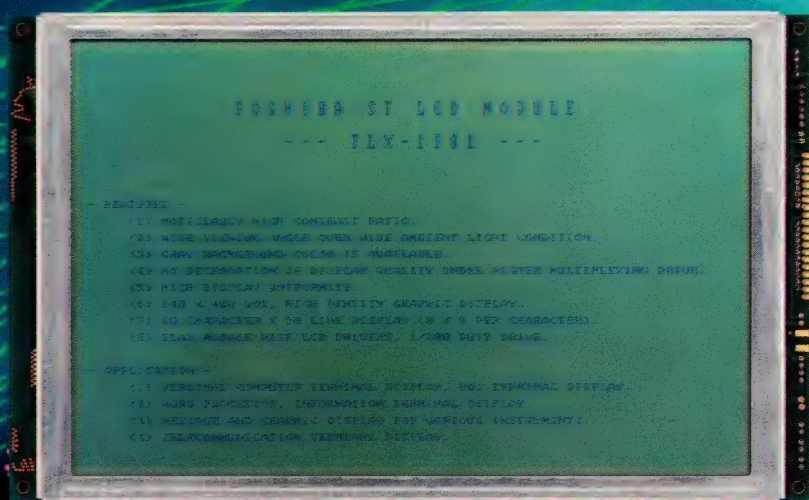
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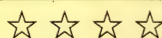
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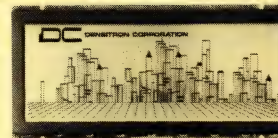
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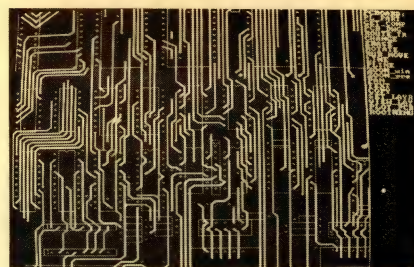
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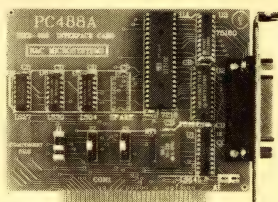
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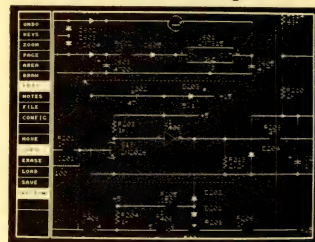
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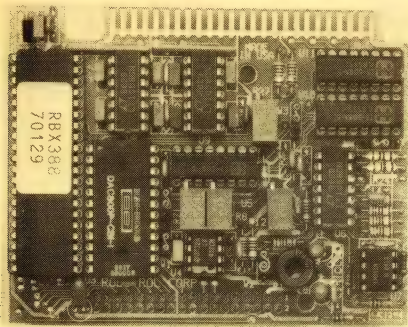
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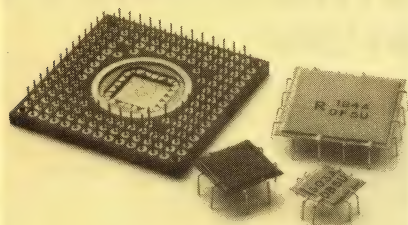
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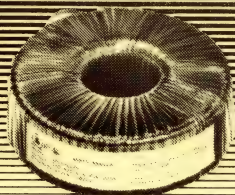


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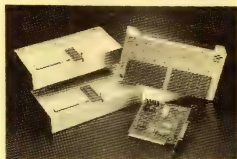
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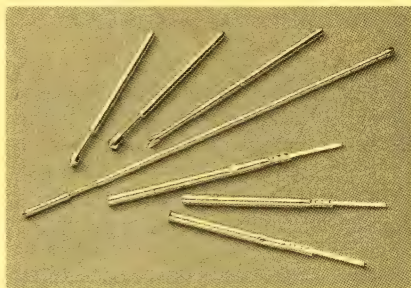
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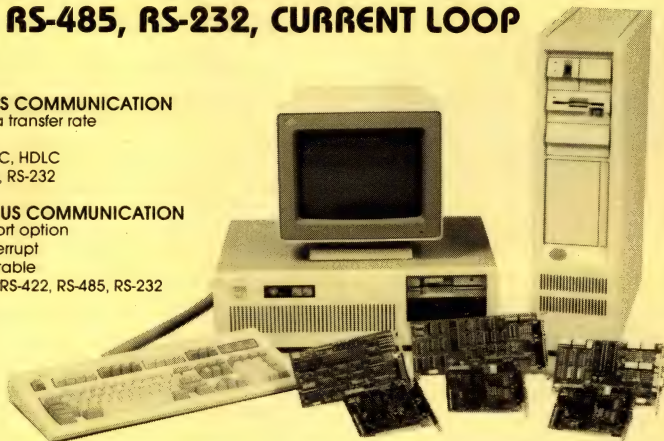
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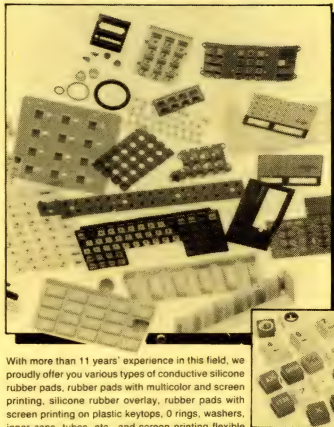
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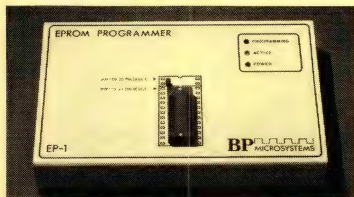
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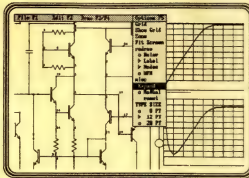


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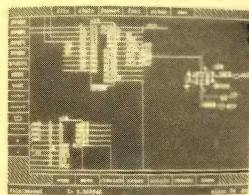
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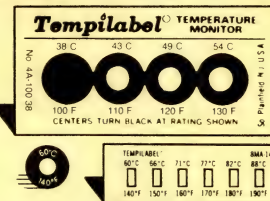
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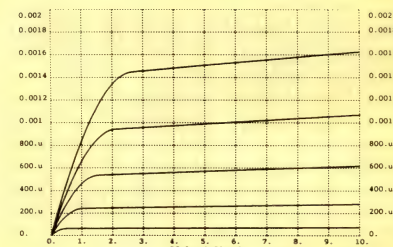


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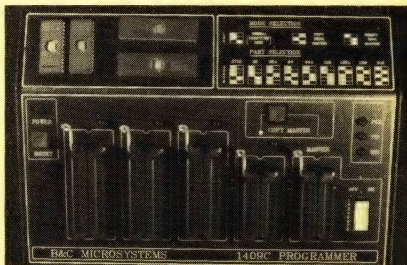
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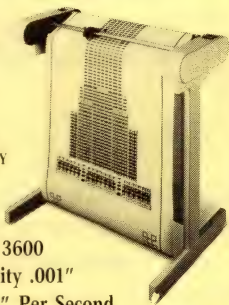
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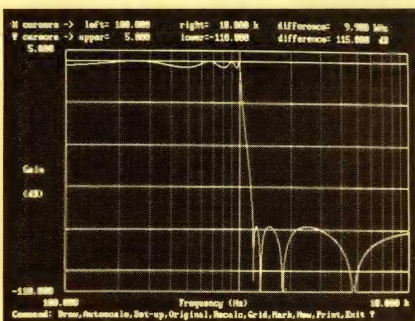
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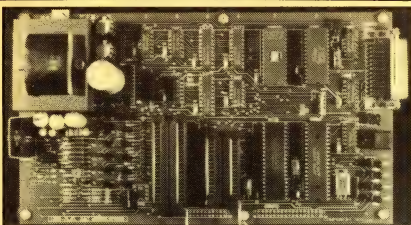


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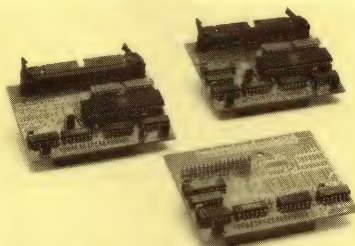
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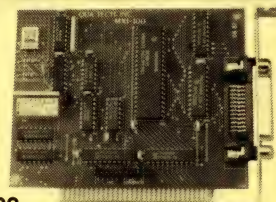
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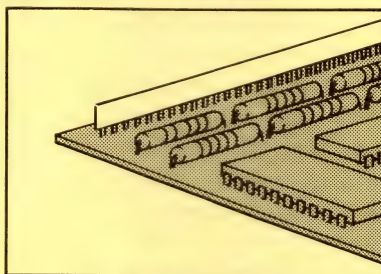
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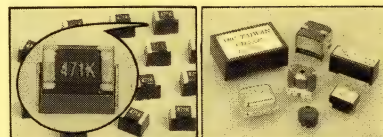
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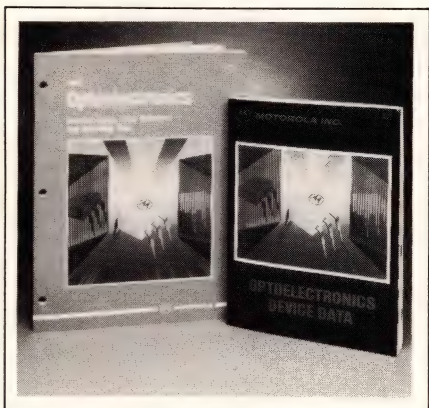


## Publications feature VME Bus and VME/Plus

The 560-pg *VME Data Book 1988* is the vendor's second edition of its data book on VME Bus products. Published simultaneously, the technical brochure on VME/Plus examines several growth-oriented architectural features. The data book contains nine chapters with numerous photos and illustrations. A product-selection matrix arranged in columns introduces each chapter. Further, a product guide helps you to locate the products you are looking for easily and quickly. The brochure features the most recent VME/Plus 32-bit devices. It also contains previews of products in the design stage, which are scheduled for release this year.

**Force Computers Inc.**, 3165 Winchester Blvd, Campbell, CA 95008.

Circle No 435



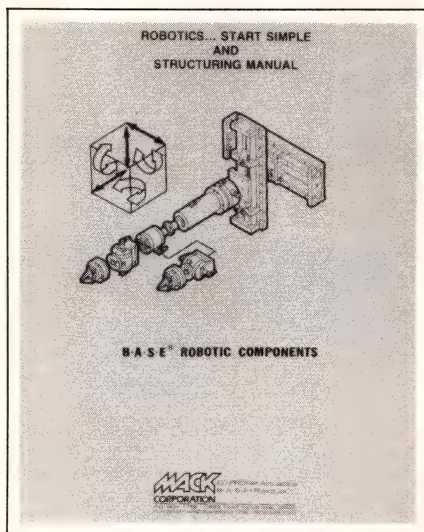
## Optoelectronics guide and data book

The two publications, *Optoelectronics Selector Guide (SG87/D)* and *Optoelectronics Data Book (DL118/D)*, are divided into product sections: emitters/detectors, isolators, slot-switches, and fiber-optic compo-

nents. The data book contains 65 new products and their applications and includes a new section on optoelectronic chips or die. Both books contain an industry cross reference and a reliability section.

**Motorola Inc.**, Technical Information Center, Box 52073, Phoenix, AZ 85072.

Circle No 436



## Document describes robotics

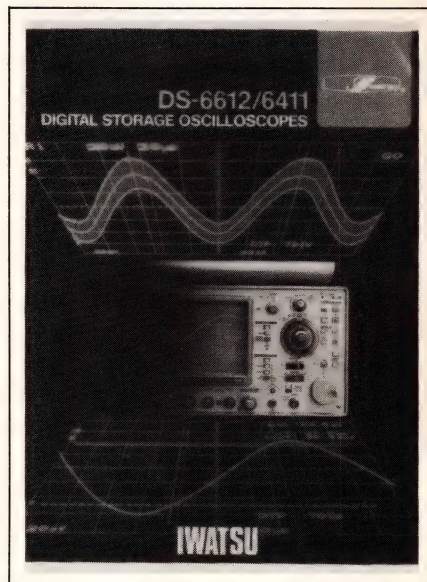
The 110-pg booklet *Robotics...Start Simple, and Structuring Manual* comprises three main sections: the fundamentals of robotics; applications and ideas; and structuring for basic automation-system elements of a nonservo robot, including a back-cover fold-out reference chart. You can use the publication as a guide to structuring a robot in the Cartesian coordinate system from standard components.

**Mack Corp.**, 3695 E Industrial Dr, Flagstaff, AZ 86002.

Circle No 437

## Digital storage oscilloscopes presented

This 6-pg, 4-color fold-out provides information about two of the vendor's digital storage oscilloscopes, the DS-6612 and DS-6411. The brochure describes each instruments' control panel in detail and lists fea-



tures and specifications. Ample illustrations are included.

**Iwatsu Instruments**, 430 Commerce Blvd, Carlstadt, NJ 07072.

Circle No 438

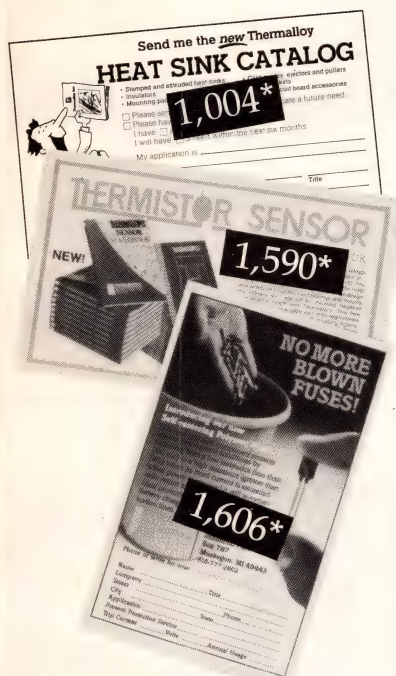


## Booklet covers lithium products

This 28-pg manual deals with lithium batteries and power modules. Besides summarizing information on the vendor's complete line of products, the publication focuses on applications, and environmental, safety, and quality data. Its array of products and procedures includes industry-standard button cells for low-cost consumer and computer



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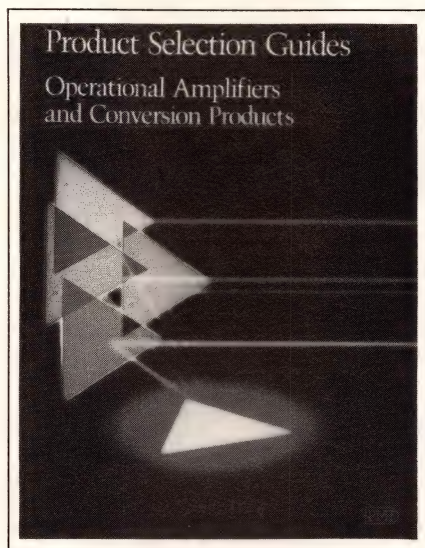
CIRCLE NO 38

## LITERATURE

memory backup applications, as well as applications in process control, data acquisition, portable equipment, and factory automation.

**International Power Sources Inc.**, 10 Cochituate St., Natick, MA 01760.

Circle No 439



### Choosing op amps and data-conversion products

The 8-pg *Product Selection Guide* features more than 80 operational amplifiers and data-conversion products. It provides information about single, dual, and quad op amps; and low-offset-voltage, low-power, low-bias-current, low-noise, high-slew-rate, and wideband amplifiers. The booklet's specification listings for 8-, 10-, and 12-bit-resolution ADCs and DACs simplify the selection of converter products.

**Precision Monolithics Inc.**, Box 58020, Santa Clara, CA 95052.

Circle No 440

### Safety-device options

This 4-pg brochure deals with the company's safe interface controls for intrinsically safe circuits and lists specifications for the vendor's Series 17, 27, and recent Series 37 controls. It reviews applications, operational modes, and FM-, UL-, and CSA-approved models. The pamphlet also provides an abbreviated

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version of the National Electric Code from the National Fire Protection Association (Quincy, MA). To help you locate the areas where intrinsically safe controls are needed, it highlights hazardous location Classes I, II, and III.

**Warrick Controls Inc.**, Box 460, Royal Oak, MI 48068.

Circle No 441

## Coverage of memory cards in credit-card format

This brochure discusses the Envoy family of microchip memory cards, which features EEPROM, EPROM, and ROM memory in a credit-card format. It provides overall specifications, EPROM/CMOS/OTP Series and EEPROM/CMOS Series specifications, a product guide, and con-



ductor specifications. The card cut-outs are pocketed in the back cover of the brochure for easy accessibility.

**General Instrument Microelectronics**, 2355 W Chandler Blvd, Chandler, AZ 85224.

Circle No 442

# Turn Good Ideas Into Good Articles

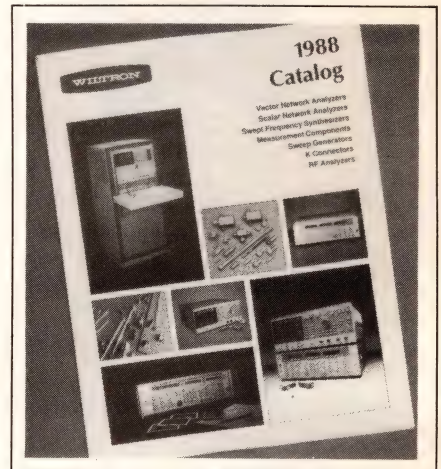
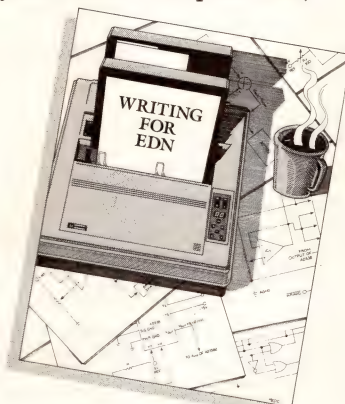
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## A catalog of microwave products

The vendor's 1988 92-pg, 4-color catalog highlights microwave measurement components, instruments, and systems in the dc to 60-GHz range. General information before each major product group helps you to make the best choice for your particular needs. The book also features complete specifications for precision measurement components; the K Connector coaxial product line,



operates to 46 GHz; and a new line of 40-GHz fixed attenuators. Other new products include vector network analyzers, scalar network analyzers, swept-frequency synthesizers, sweep generators, and RF analyzers.

**Wiltron Co.**, 490 Jarvis Dr., Morgan Hill, CA 95037.

**Circle No 443**

## Static RAMs and programmable logic devices

The company's 102-pg catalog provides specifications for its complete line of high-performance PLDs and memory devices. It includes detailed information about advancements in E<sup>2</sup>CMOS PLD technology, the GAL (generic array logic) 39V18, and the GAL 16Z8, as well as specifications for the E<sup>2</sup>CMOS GAL and high-speed static RAM devices. Further, the publication features application notes and a

sales office directory.

**Lattice Semiconductor Corp.**, Literature Services Dept, Box 2500, Portland, OR 97208.

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## Graphics aid for surface-mount drawings

This surface-mount footprint template assists you in generating printed-circuit artwork. It includes the most commonly used component shapes, and it provides accurate scale match (×4) to the vendor's line of artwork design aids. \$7.25.

**DMC Designmaster**, Box 876, Camarillo, CA 93011.

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## Programmable sweep generators available

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erators. It describes the series' operation, display, frequency, and power sweep, as well as its ease of calibration and user programming. It also includes complete specifications for the series.

**Marconi Instruments**, 3 Pearl Ct., Allendale, NJ 07401.

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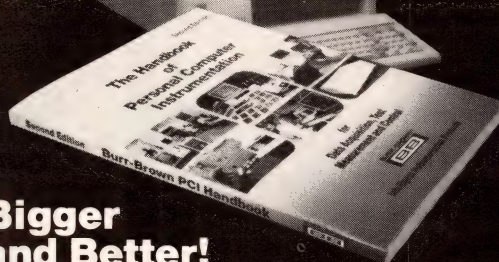
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## PROFESSIONAL ISSUES



Kris Stevenson

# Change is coming for performance reviews, but it's slow and painful

Deborah Asbrand,  
*Associate Editor*

The good news about performance appraisals is that companies are finally starting to take them seriously. The bad news is that the review process is still so dreaded and steeped in misunderstanding that improvements are minimal.

"Performance appraisal is a no-win situation," concedes Bob Glen of the Naval Weapons Center at China Lake (CA). Glen recently managed a project that involved re-vamping the performance-appraisal system used for 5000 employees at the China Lake and San Diego naval bases. Conducting an evaluation and being evaluated, Glen said at the IEEE's 1987 conference on engineering careers, are "probably the most stressful things you can do. But there's no way around them."

It's small wonder, then, that for most employees, annual reviews entail the strained nervousness of a

superpower summit conference. Employees step into their manager's office and wait to hear the category or label—unsatisfactory, satisfactory, or above average—to which the year's 50-odd weeks of work have been reduced. But subordinates aren't the only ones who shudder at the thought of yearly assessments. Managers report that they feel just as much, and maybe more, tension.

The problem with performance

appraisals is that many businesses pay them only lip service. Instead of serving as an opportunity for a manager and subordinate to meet and constructively discuss the latter's professional strengths and weaknesses, the annual event is, by design, an exercise in paperwork by which the employer substantiates salary increases and promotions. For most workers, reviews are empty rites of the workplace: Employees need feedback on their performance every day, not just one day a year. And since few managers are trained to provide such support, companies are left with the task of salvaging some usefulness from a system of infrequent reviews.

Human-resource professionals gamely try to help. Performance appraisal is a favorite topic among training professionals, says Patricia Galagan of the American Society of Training and Development (Alexandria, VA). The organization's monthly magazine, *Training and*

**Appraise** (ə-prāz): **1.** To set a value on, estimate the amount of **2.** To evaluate the worth, significance, or status of; *especially*, to give an expert judgment of the value or merit of  
—*Webster's Ninth New Collegiate Dictionary*



## PROFESSIONAL ISSUES

*Development Journal*, runs several articles each year on implementing and improving performance-appraisal systems. Galagan, the magazine's editor, says the publication's 50,000 readers are hungry for information on the topic because "professionally, they believe it's important." But fueling their interest, she adds, are "the companies they work for," many of which are looking to improve their review systems.

Indeed, after years of viewing employee evaluations as a necessary evil, more American businesses are waking up to the advantages they can derive from a well-planned performance-appraisal system. Until recently, human resources was the stepchild of corporate culture, says Gary Latham, chairman of the University of Washington's management and organization department. But currently, he says, "there's the realization that we've put maximum efforts into finance and technology, and that we now have to put as much emphasis on our internal systems."

Many corporations, too, are seeking to eliminate cost-of-living salary increases and adopt a pay-for-performance system. Implementing merit pay, though, leads many businesses back to their appraisal processes. "Companies are finding that they can't begin to pay for performance until they're able to define what good performance is," says Audrey Ellison, marketing manager for Organizational Dynamics, a Burlington, MA management-training and consulting firm.

Also attracting employers' interest is the important role that review documents play in lawsuits that employees file against former employers—and the large sums that courts have been awarding employees for damages. For example, nine laid-off employees of Miles Inc, the maker of Alka Seltzer, sued the company for age discrimination. They claimed that they were given pink slips because of their ages, not their job performance; Miles countered that

only the workers who performed most poorly were dismissed in the company-wide layoff. Miles lost the suit and in August 1986 was ordered to pay the workers \$1.63 million in damages. Key to the fired employees' victory were copies of their performance reviews, which contained glowing descriptions of their abilities.

### The paper chase

Parting with time-honored systems, though, is not easy. Many companies, for example, believe that revamping their evaluation forms can bring substantive change to their review systems. Studies, however, show that the arrangement of evaluation-form questions or the way they're phrased has little bearing on a review system's effectiveness. "Generally, all of the tools

**For most employees, annual reviews entail the strained nervousness of a superpower summit conference.**

seem to work if the people using them believe in them," says Pat Gallegos, personnel director for Evans and Sutherland Computer Corp, a Salt Lake City, UT maker of high-end graphics terminals. "Whether you use a blank sheet of paper or a ranking system doesn't really matter."

Relinquishing old attitudes about performance appraisal is even more difficult. The review process is an emotional mine field for managers and employees alike. "There's a lot of fear surrounding the process on both sides," says Richard Swanson, director of the University of Minnesota's training and development research center. "Supervisors don't feel comfortable being in a godlike position and judging people. So they avoid it."

Newly promoted or ill-trained managers are often unprepared for the hurt feelings and deflated egos that result from poorly conducted reviews. Don Wilson says that on first becoming a manager at Bell Laboratories in the 1960s, he expected to conduct performance reviews in the workmanlike fashion that he performed his other responsibilities. He quickly recognized his mistake. "I didn't think about how I was shaping the person on the other end of the process," he says. "It was only when I saw people were hurt that I realized how devastating [the performance review] can be to self-esteem."

Performance appraisals bring "a great deal of trauma to both parties," says Wilson, now a telecommunications researcher for Bell Communications Research in Morristown, NJ. Thirty-five years of reviewing and being reviewed have convinced Wilson of the futility of ranking, rating, and categorizing employees. "We're spending a lot of energy trying to measure very small differences between people and placing a great deal of importance on those differences."

Engineers, in particular, scoff at the quirks of the review process, so much of which hinges on the skills—and idiosyncracies—of the manager conducting the evaluation. Few performance-appraisal problems are occupation-specific, but consultants and researchers agree that engineers, whose field is so precise, chafe at the personal and subjective process of job reviews. "People in engineering always say that performance appraisals aren't objective or measurable enough," says Norman Smallwood, a partner of Novations Group Inc, a Provo, UT, consulting firm. "But the simple truth is that [judging] performance is always subjective."

The chief obstacle to achieving more communication and less measurement is management's reluctance to abandon the once-yearly



## PROFESSIONAL ISSUES

review system. Feedback needs to occur regularly, human-resource officials say, not one day each year. Latham points to sports as the best example of how frequent discussions benefit performance: Coaches "don't wait until the end of the season to let people know what they're doing wrong."

Once-a-year reviews attempt to accomplish too much in too little time. In addition to covering an employee's job performance and rating, the review discussion often includes pay increases, possible promotion, and career guidance. As a result, employees leave their manager's office shell-shocked. "People are told that they're average performers, [and] they start to stew," says Smallwood. "Then they're told about a salary increase—which, because they're still stewing, they may not even notice—and then the manager says 'Now let's talk about your career.'"

Yet persuading companies to dismantle a system of annual reviews is difficult because most can't envision a replacement for it. "Companies want to part with it because it's not working, but the question they ask is 'how?'" says Ellison.

Experts agree that the first step to solving review-process problems is to conduct performance appraisals several times a year. Often, appraisals constitute the only opportunity employees have of receiving feedback on their work, and "they need to be done at least quarterly to do any good," says Latham. "Think about the surprise quizzes that you took in school. When you arrived in class, the teacher announced the quiz and instructed you to place your books under your seat. You hated it, but, boy, did you study for that class. Performance is at a maximum in that kind of class."

At the very least, says Latham, salary and promotion reviews should be conducted independently of performance reviews, particularly if employees are asked to perform

self-evaluations. "Self-evaluations are worthwhile so long as money and promotion opportunities aren't tied to them," Latham says. "Then it's like asking the person to testify against himself."

The next task is helping managers to kick their dependence on the paperwork of the process and learn the art of constructive conversation. "Managers need to learn to explain their position," Gallegos says, "not defend it."

### Feel like a number

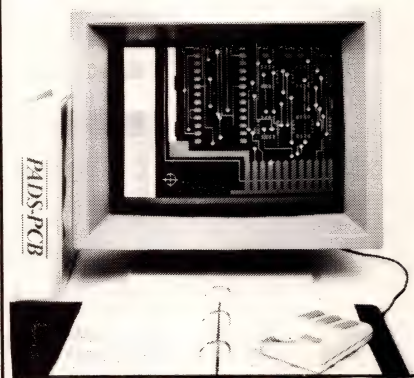
The good news for employees is that the authors of human-resource studies are now turning their attention from the tools of appraisal to the targets of those tools—the employees. Researchers are examining how people respond to interviews and the ways in which they can disagree without feeling defensive.

A more humane system of appraisal, however, seems a long way off. The June 1987 issue of *Training and Development Journal* contained a monograph entitled "An uneasy look at performance appraisal," which has been widely cited by training professionals. In the article, the late Douglas MacGregor criticized the cold, assembly-line-like quality of most review systems. "As far as the assumptions of the conventional appraisal process are concerned," MacGregor wrote, "we still have what is practically identical with a program for product inspection."

MacGregor's theories are not controversial. Indeed, they are in close agreement with those of other industry experts. So, why has his monograph generated so much commentary? Because it's 30 years old, a reprint from a 1957 issue of the *Harvard Business Review*. **EDN**

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Mar. 31	Mar. 10	Power Semiconductors, Memory/Graphics, Fiber Optics	
Apr. 14	Mar. 23	Communication Technology Special Issue, Communication Systems	Closing: Mar. 31 Mailing: Apr. 21
Apr. 28	Apr. 7	Software, Industrial Computers, Interface ICs	
May 12	Apr. 21	Analog Technology Special Issue, Analog Converters	Closing: Apr. 28 Mailing: May 19
May 26	May 5	CAE, Software, Sensors/Transducers	
June 9	May 19	CAE, Analog ICs, Test & Measurement	Closing: May 29 Mailing: June 16
June 23	June 2	Data Communications, DSP, Components	
July 7	June 14	Product Showcase—Vol. I, Power Sources, Software	Closing: June 23 Mailing: July 14
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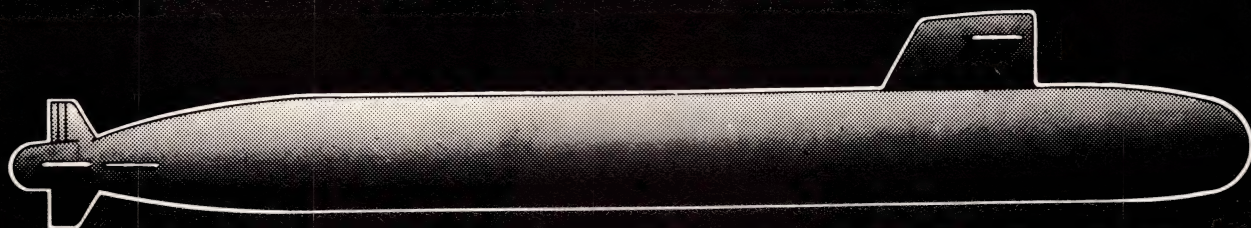
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Qualify with a BSEE or BSME plus three years' experience in the following areas: digital and analog component evaluation and failure analysis; electromechanical failure analysis and problem resolution specifying electrical and mechanical component requirements (resistors and capacitors through VLSI and ASICs); SMT components; component supplier interfacing on specifications and quality improvement; disk drives. Experience in INTEL 80286/80386 Assembly language programming is preferred.

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Familiarity with Teradyne L200 and Genrad test equipment, "C" and Assembly programming languages, using industry standard architecture and MS-DOS in an 80286/80386/8086 environment is essential.

## **Component Test Engineers:**

You'll ensure quality control through engineering analysis, device characterization, and failure verification of digital and linear devices such as: custom ASICs,

complex microprocessors and peripherals, advanced CMOS logic, static and dynamic memories, and other precision components.

You should have a BSEE and three years' experience in either ATE component test equipment, analog testing, printed circuit boards, component/incircuit boards, or vendor quality inspection and supplier selection.

## **Vendor Quality Engineers:**

Coordinate device qualifications with vendors and purchasing. You'll lead the way conducting tests and evaluating design and redesign peripheral problems to maintain the highest user satisfaction ratings through quality control. You must have at least two years' experience with peripherals and project management, plus a BSIE or BSEE degree.

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or other related engineering field, with two years' experience in digital systems design. In addition, you should have excellent communication skills and the ability to move multiple projects toward completion.

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## **Microprocessor Logic and ASIC Design Engineers:**

Challenge your expertise in high-speed logic design and/or microprocessor system design using flow charts and timing diagrams for digital design and detailed design analysis.

Your experience should include vendor libraries, test vendor generation, simulation checkout, and TTL emulators for gate array standard cell design. Familiarity with CAE systems used in logic design, test vector generation, simulation checkout, and documentation is also necessary. You must have five years' related experience plus a BSEE or equivalent degree; an MSEE degree is preferred.

## **Systems Software Engineers:**

Evaluate, design, and develop firmware, operating systems, device drivers, and utility software for PC systems. You'll need a BSCS, BSEE or equivalent degree with four years' related experience in PC software development, 8086/286/386 Assembly/"C" language programming in MS-DOS, OS/2, and/or UNIX/XENIX operating systems.

## **Systems Architects:**

Design new products by investigating and evaluating system compatibility and performance of design alternatives and new technologies. You'll develop hardware

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Qualify with a BSEE, MSEE preferred, and three years' hardware background with a knowledge of microprocessor-based systems software. In addition, experience with CPUs/memory/bus architecture, numeric co-processors, file subsystems, network/communications, graphic subsystems, and state machines is required.

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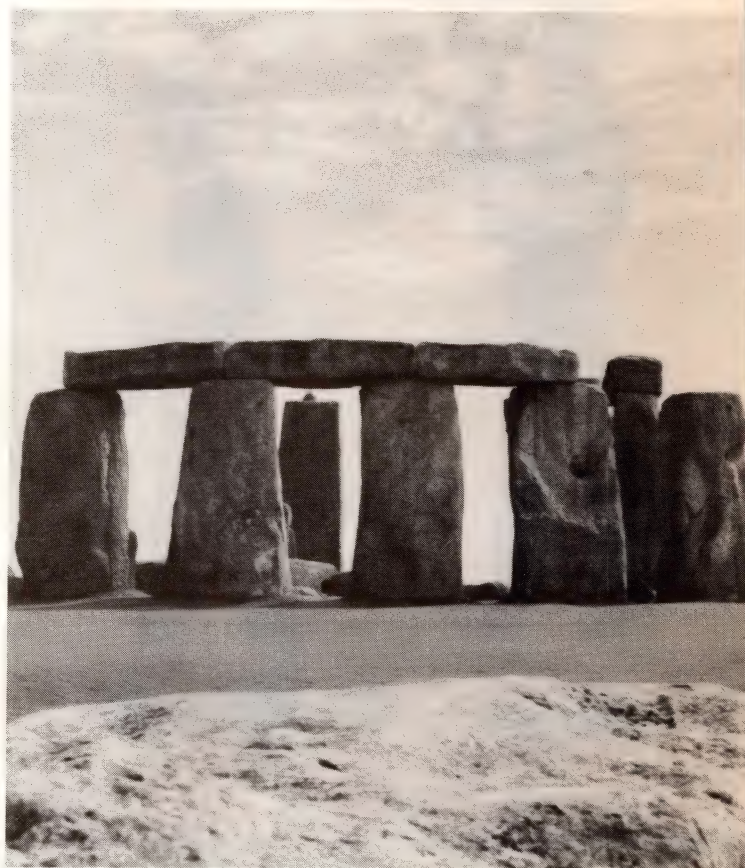
Stonehenge, one of the most famous of all the classical megalith monuments, has long been an important part of the popular and scientific imagination. Its origin has been the cause of speculation for years, as scientists try to discern who had the intellect and ingenuity to create a celestial observatory of such astronomical significance and exactness.

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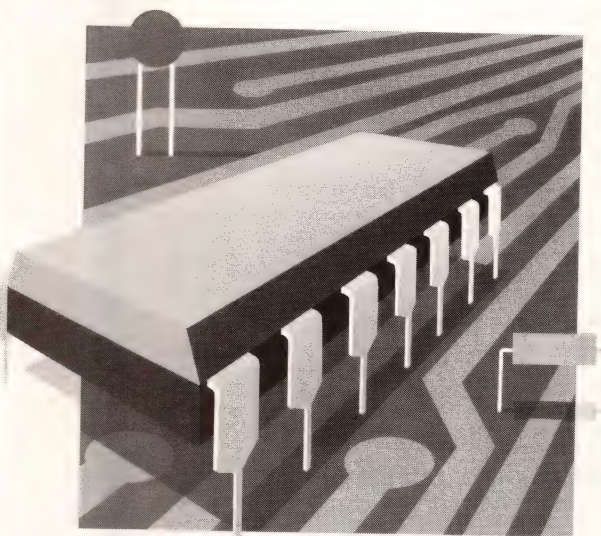
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Reporting to the Manager of PCB Assembly, this position is responsible for directing the activities of the Industrial Engineering Group who support all the major product lines in this microcircuit manufacturing facility. Included is the development, modification and documentation of the process, flow diagrams, visual line aids for the assembly operations and labor rate standards and line balance audit. Also responsible for reviewing equipment capacity and performing operational analysis time studies.

Experience in the fabrication of conventional and SMD PC Board assembly is required. Familiarity with polymer, thick film or chip and wire microcircuits would be beneficial. BSIE required.

### **QUALITY ASSURANCE ENGINEER**

This individual will establish the measurements and process controls necessary to detect entry of any factors that might adversely affect product quality or reliability. Also, this position will develop and implement quality levels and appropriate defect classification for quality rating of assembled products.

A BSEE or equivalent along with 2 years experience in the setting-up and usage of statistical process controls is required.

### **TEST EQUIPMENT SECTION MANAGER**

Reporting to the Plant Manufacturing Engineering Manager, this position will be responsible for developing and implementing test systems and production equipment improvements which will result in improved reliability and overall performance. This individual will also manage test systems maintenance, spare parts inventory and upgrades to existing equipment.

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Position involves maintaining equipment for optimum performance of laser systems, which will include development of laser trim programs, and training personnel in set-up and operations.

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# ADVERTISERS INDEX

Abbott Transistor Labs Inc	305	Fujitsu Components of America Inc*	236	Philips Test & Measuring Instruments Inc**	117
ABC-Taiwan Electronics Corp	323	Fujitsu Limited**	6	Phillips Chemical Co	46
Academic Press/A Division of HBJ Publishers	283	Fujitsu Microelectronics Inc*	168	Pioneer Magnetics	79
ACCEL Technologies Inc	323	Gates Energy Products Inc	77	Plessey Microsystems	198
ACDC Electronics	307	GCOM Inc	259	Plessey Microsystems/Defense & Custom Products	272
Acopian Corp	208	GE Plastics	191	Plessey Optoelectronics**	168
Acromag Inc	138	General Silicones	320	Power Conversion	124
ADPI	320	GE/RCA Intersil Semiconductors	28-29, 68-69, 106-107	Powerline	274
Advanced Micro Devices	12-13	Germanium Power Devices	86	Power-One Inc	39
Aerovox Mallory	267	Gould Semiconductor*	66	Powertronic	179
Airpax Corp/Cambridge Div	277	Grayhill Inc	246	Precision Monolithics Inc	193
Alexander Batteries	320	3-H Industries	145	Pro Lib Inc	318
Amco Engineering	312	HEI Inc	255	Qua Tech Inc	320, 323
American Automation	146	Heurikon Corp	294	Qualidyne Systems Inc	290
Amoco Laser Co	231	Hypertronics Corp	285	Robinson-Nugent Inc	70-71
AMP Inc	142-143	I-Bus Systems Inc	283	Robotrol	319
Amphenol/Spectra-Strip	44	ILP Manufacturing Inc	319	Rogers Corp	323
Analog Design Tools Inc	45	Inmos Corp	238	Rohde & Schwarz**	20
Analog Devices Inc	50-51	Instant Board Circuits Corp	34	Samsung Semiconductor	288-289
Antex Electronics	258	Integrated Device Technology Inc	166-167	Samtec Inc	129
Applied Data Systems	318, 322	Integrated Circuits	322	Saratoga Semiconductor	47
Applied Microsystems Corp	14-15	Intel Corp	58-59	SBE Inc	178
Ariel	317, 319	Intermetrics Inc	100	Schroff	162
Arium Corp	194-195	International Rectifier	C3	Seagate Technology	245
Arnold Magnetics Corp	256	Introl Corp	293	Seeq Technology Inc	33
AT&T Technologies	81, 82-83	Intronics	310	Seponix	299
Augat Termination Products	262	Intusoft	321	SGS-Thomson Microelectronics	116-117
Augat-Interconnection Components	227	I/O Tech	304	Sharp Corp	298
Avocet Systems Inc	319	JETA Power Systems	253, 255, 257, 259, 261	Sharp Electronics	197
B&B Electronics Mfg Co	320	John Fluke Manufacturing Co Inc	6, 67, 229	Siemens Components Inc*	147
B&C Microsystems	318, 321, 323	KEC Electronics Inc	218	Silicon General	122
Belden Wire & Cable	292	Keithley Instruments	131-136	Silicon Systems Inc	126-127
Bering Industries Inc	269	Kepco Inc	291	Silvar-Lisco	301
Berkley Varitronics	317	Key Tronic	205	Simpson Electric Co	230
Bertan Associates Inc	297	Laube Technology	261	Single Board Solutions	323
Bourns Inc	109-114	Lectromagnetics Inc	300	Sonnenschein Batteries Inc	279
BP Microsystems	321	Lemo USA Inc	159	Sorensen Co	287
Brooktree Corp	248-249	Linear Technology Corp	233-234	The Soundcoat Co	327
Bud Industries Inc	264	Littelfuse Inc	260	Spectrum Software	99
Burr-Brown Corp	232, 257, 327	Logical Devices Inc	317	Sprague Electric Co	97
BV Engineering	322	LPKF:CAD/CAM Systems	120	Standard Grigsby Inc	290
Bytek Corp	311	3M Fluorinert	101, 102-103, 104	Standard Manufacturers Group	65
CAD Software Inc	331	Maple Systems	322	Stimpson Co Inc	216
CADdy Corp	314	Marconi Electronic Devices	271, 273	Sun Microsystems	40-41
Cadnetix Corp	84-85	Marshall	163	Switching Power Inc	137
California Eastern Labs Inc	182	MathSoft Inc	124	Taiwan Liton Electronic Co Ltd	309
Capital Equipment Corp	320	Matrox Electronic Systems Ltd	243	Tatum Labs	321
Carlingswitch	74	Maxim Integrated Products	72	TDK Corp	139
Castrol Inc	278	McLean Engineering	302	Tektronix Inc	8, 94, 125
CCP Contact Probes Enterprise	320	Measurement Systems Inc	270	Tempil Div	321
CDI Corp—West	322	Melcher	216	Teradyne Inc	30-31
Central Data Corp	175, 177	Mentor Graphics Corp	10-11	Thomas and Betts Corp	263
Ciprico Inc	25	Methode Electronics Inc	32	Todd Products Corp	317
C&K Components Inc	180	Micro Dot Inc/Malco	280	Tokin Corp	296
Coilcraft	328	Micro Networks	250-251	Toshiba America Inc/Semiconductor Div*	18-19
Comair Rotron Inc	270	Micro Switch	274-275	Toshiba Corp	316
Communications Specialists Inc	322	Micro/Sys	34	Trend Circuits	C2
Computer Products Inc	87-92	Mini-Circuits Laboratories	26-27, 241, 342	TRW/LSI Products	23
Conversion Devices Inc	318	Mizar Inc	217	Utilec Inc	161
Cyclone Microsystems Inc	108	Molex Inc	60	Vicor	295
Cypress Semiconductor	52	Motorola Semiconductor Products Inc	42-43	Vishay **	229
Daisy Systems Corp	48-49	Multibus Manufacturers Group	35-38	Visionics Corp	322
The Dan Pepper Co	314	Murata Erie North America Inc	157	V-Metro	286
Data I/O Corp	C4, 303	NCR Power Systems	4	VTC Inc	2
Deltron Inc	278	NEC Corp	181	Wavetek San Diego Inc	3
Densitron Corp	317	NEC Electronics Inc	282	Wintek Corp	318, 323
Design Computation Inc	323	NMB Semiconductor Corp	141	Wollongong Group	98
Dialight Components	56-57	Nohau Corp	317	Xender Corp	319
Digital Media Inc	319	Northwest Instrument Systems	20	Xentek	254
Diversified Technology	253	OKI Semiconductor	164-165	Xycom	16-17
EG&G Almond Instruments	268	Omaton Inc	318	Zendex	115
EH Titchener & Co	320	Omnibyte Corp	168A-B	Zenith Radio Corp	216A-D
Elan Digital Systems	325	One/D	318	Zericon	322
Electrochem	276	Optical Fiber Technologies/(OFTI)	318	Ziatech Corp	1
Electro-Mechanics	321	OrCAD Systems Corp	252	Zilog Inc	121
Electronic Development Corp	270	Oyster Terminals	306	Zitek Corp	206-207
Electronic Solutions	118	Panduit Corp	196	Zippy Shin Jiuh Corp	321
Elek-Tek	304	Papst Mechatronic	281		
EMP Engineering	319	Philips Elcoma Div**	66-67		
Endicott Research Group	302				
Engineering Tutorial Software	318				
Epson America Inc	313				
Ferranti Electric**	194				
Force Computers Inc	54-55				

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# LOOKING AHEAD

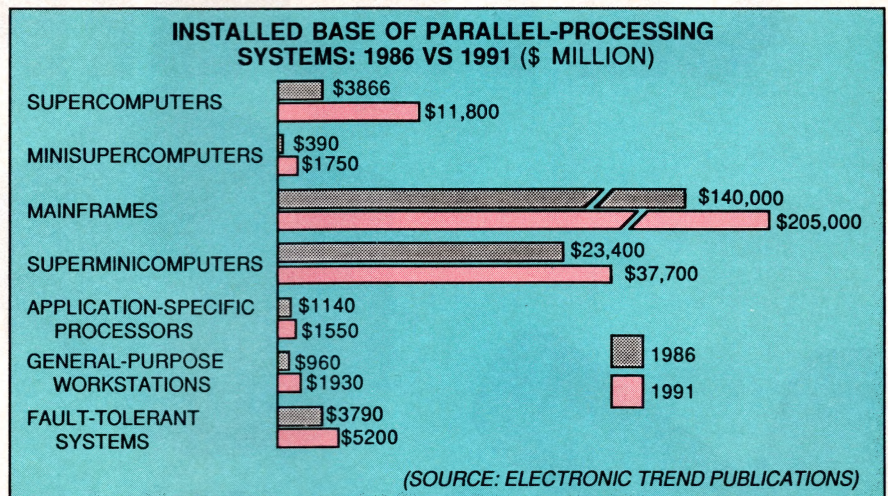
EDITED BY CYNTHIA B RETTIG

## Parallel processing spurs high-end-computer growth

Parallel-processing architectures will account for 26% of the growth in the worldwide high-performance computer market from 1986 to 1991, according to a report by Electronic Trend Publications (ETP) of Saratoga, CA. In 1985, total revenues from systems shipped in this market equaled \$20 billion. In 1990, revenues will be \$39.6 billion, and 48% of all systems shipped will incorporate some form of parallel-processing design. Although mainframes and superminicomputers will represent 87% of the 1990 market's dollar value, a new class of computers—including minisupercomputers, data processors, array processors, and symbol processors—will account for more than \$1 billion of the market's value. The value of the total installed base of parallel-processing machines, which was \$173.5 million in 1986, will rise to \$264.9 million by 1991.

In the early stages of the market's growth, the demand for parallel-processing machines will come primarily from the scientific and technical fields. However, as 1990 approaches, the drawbacks of alternative processing methods will augment the growth of parallel-processing systems. ETP's report points out a number of these drawbacks. In the first place, single-processor-based architectures are reaching their theoretical limits in terms of speed. Further, I/O linkages in application-specific array processors and networks can be slow. Finally, general-purpose minicomputers and mainframes will simply prove unsuitable for high-performance computing, for which application-specific systems will prove necessary.

Because parallel processing uses multiple arrays of CPUs simultaneously, it can achieve speeds 10 to 100 times faster than can the older, uni-processor systems. Hardware or



hardware-related issues crucial to parallel processing include VLSI circuitry, gallium arsenide ICs, megabit-memory-chip development, improved internal channel speeds, hybrid optoelectronic circuitry, and better technology for cooling circuitry. All of these key elements are either under development or already available.

Software development for parallel-processing systems is proceeding more slowly, however. ETP identifies three major stumbling blocks in this area: the design of operating systems specifically geared for parallel operation, confusion about a standard for higher-level languages, and the problem of designing appropriate language compilers.

## EMI/RFI market to exceed \$8 billion by 1993

From 1983 to 1986, the market for EMI-shielding equipment and facilities grew from \$540 million to more than \$1 billion. By 1993, the market will exceed \$8 billion, according to MIRC (Market Intelligence Research Co) of Mountain View, CA. Increased demand from government, military, and industrial sectors will drive this healthy growth rate.

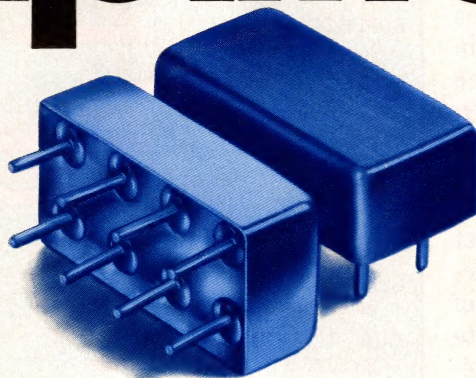
The sophistication of modern electronic equipment and a heightened awareness of security needs have made EMI a critical issue. Industry in general has become more concerned about how EMI influences product performance, and the government and military sectors are placing increasing emphasis on protection from security leaks. At the same time, EMI-shielding products are steadily growing more dependa-

ble, more attractive in price, and better looking.

MIRC divides the market for EMI-shielding equipment and facilities into two major segments: architectural shielding structures and shielding for electronic equipment. Suppliers of architectural shielding structures are striving to provide turnkey services to customers. Among their products are windows with such features as wire mesh and transparent conductive coatings; room enclosures, which include both welded stand-alone and modular products; doors and walls; and building materials and related services. Suppliers of electronic-equipment shielding offer such products as paint; zinc arc spray; plating; conductive plastics; and minor products such as conductive foils, tapes, gaskets, and sealants.



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## 1000V HEXFETs®

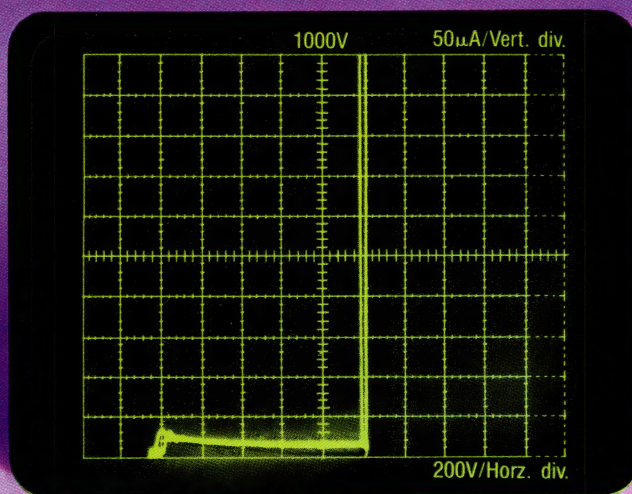
Some so-called high voltage power MOSFETs just can't seem to deliver what they promise. But HEXFETs offer exceptional stability in three new *optimized* high voltage families: 800V, 900V and 1000V.

Each voltage is paired to a specific  $R_{ds(on)}$  value for the best cost-per-amp ratio. So you can spec just what you need without straining your design budget.

Our high voltage TO-3 HEXFETs can handle your heavy industrial and hi-rel requirements. For less demanding applications, you can choose TO-220 or TO-3P case styles.

No matter how you mix and match these HEXFETs, they all provide faster switching and high blocking voltage capabilities. Plus *guaranteed* repetitive avalanche and dynamic  $dv/dt$  ratings – two extra safety margins at no extra cost.

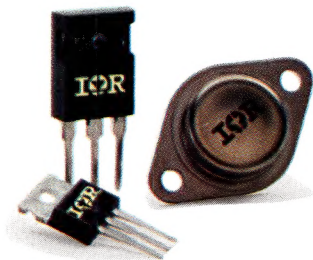
The complete HEXFET power MOSFET line is described in our new 1987 catalog. Write for your free copy. Or call (213) 607-8842.



Example of 1kV HEXFET Stability: After 1000 hours of HTRB testing, TO-3 device performs beyond rated voltage with no current leakage.

Available Packages With Corresponding  $R_{ds(on)}$  Values

Voltage Ratings	TO-3, TO-3P and TO-220AB		TO-3 and TO-3P	
800V	6.5Ω	3.2Ω	2.0Ω	1.2Ω
900V	8.0Ω	4.0Ω	2.5Ω	1.6Ω
1000V	11.5Ω	5.6Ω	3.5Ω	2.0Ω



**Most HEXFETs now in stock  
for immediate delivery!**

**Number 1 in  
power MOSFETs**

**International  
Rectifier**

**WORLD HEADQUARTERS:** 233 KANSAS ST., EL SEGUNDO, CA 90245, U.S.A. (213) 772-2000. TWX 910-348-6291, TELEX 472-0403  
**EUROPEAN HEADQUARTERS:** HURST GREEN, OXTED, SURREY RH8 9BB, ENGLAND TELEPHONE (0883) 713215. TELEX 95219

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**CIRCLE NO 222**





# THE UNISITE 40 PROGRAMMER: BECAUSE STATE-OF-THE-ART IS A STATE OF CHANGE.

## PROGRAMMING TECHNOLOGY THAT SUPPORTS ADVANCED DESIGNS— TODAY AND TOMORROW.

The UniSite™ 40's universal programming technology is the fastest and easiest way to keep up with new devices and packages. Its software-configured pin driver system provides a single site for programming any DIP device up to 40 pins, including PLDs, PROMs, IFLs, FPLAs, EPROMs, EEPROMs and microcontrollers. The same site accommodates the most popular surface-mount packages—PLCCs, LCCs and SOICs.

And now the UniSite 40 is also a gang/set programmer. With the new SetSite™ module, you can program and test as many as eight devices, up to 40 pins each, simultaneously.

## INSTANT ACCESS TO NEW DEVICES.

The UniSite 40's universal pin driver



electronics stores device-specific instructions on a 3 1/2" micro diskette. To update your UniSite 40 with the latest device releases, simply load a new master diskette.

**FAST, EASY PROGRAMMING.** Menu-oriented operation with step-by-step prompts makes programming simple.

Or bypass the menus and zoom directly to specific operations by selecting key commands. Help messages are available whenever you need assistance.

To speed parts selection, the UniSite 40 provides a built-in list of devices. And you can save your most frequently-used programming parameters for instant recall.

## DESIGN FREEDOM FOR TOMORROW.

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